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(54) **SELF-DRIVING VEHICLE SYSTEMS AND METHODS**

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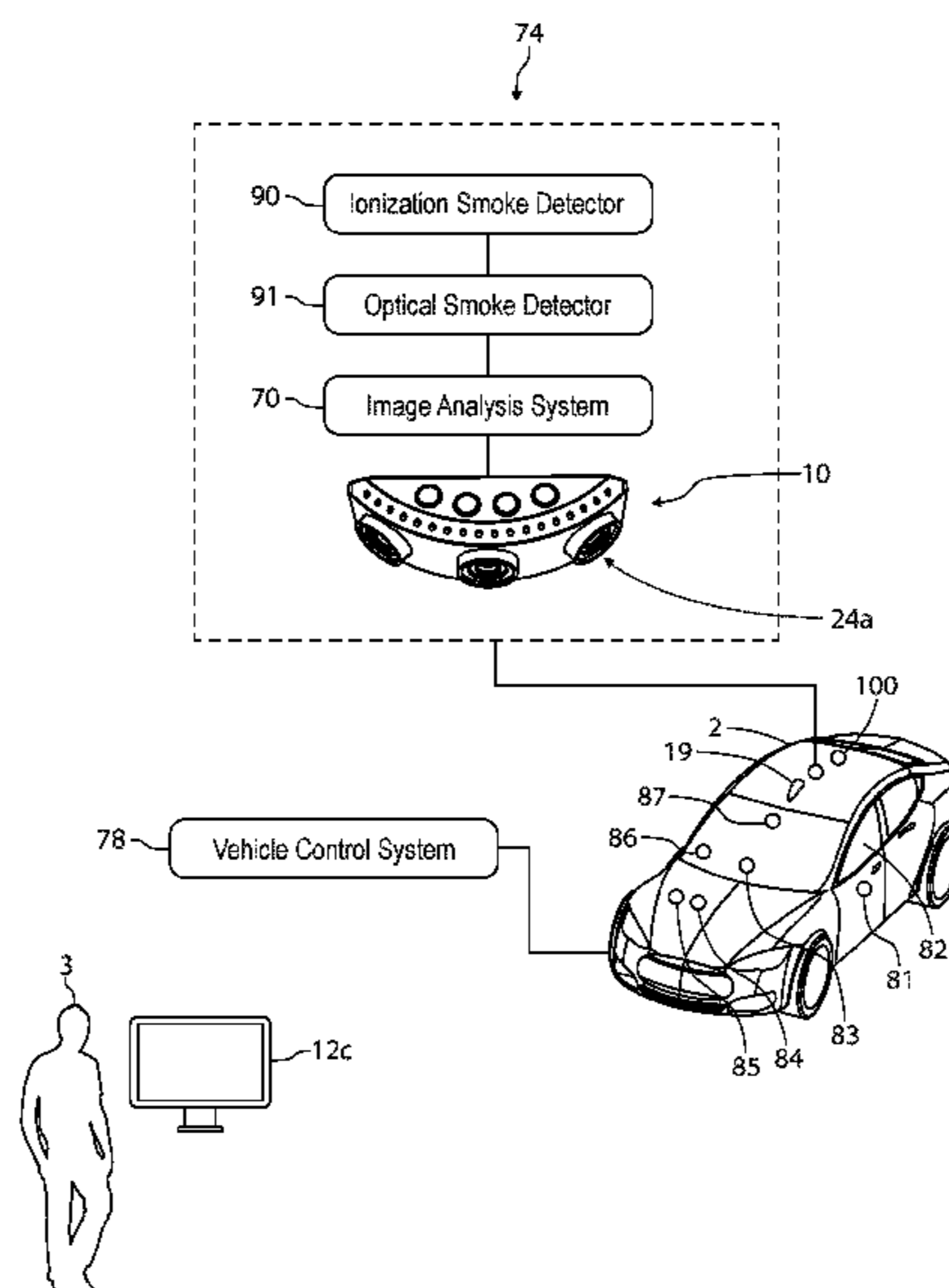
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Primary Examiner — Travis R Hunnings

(57) **ABSTRACT**

A maintenance system can be used with a self-driving vehicle. The maintenance system can include a vehicle management system configured to autonomously drive the vehicle. The maintenance system can include a smoke detection system configured to detect smoke inside the vehicle and a communication system configured to send wireless communications to a remote computing device in response to the smoke detection system detecting the smoke.

30 Claims, 10 Drawing Sheets



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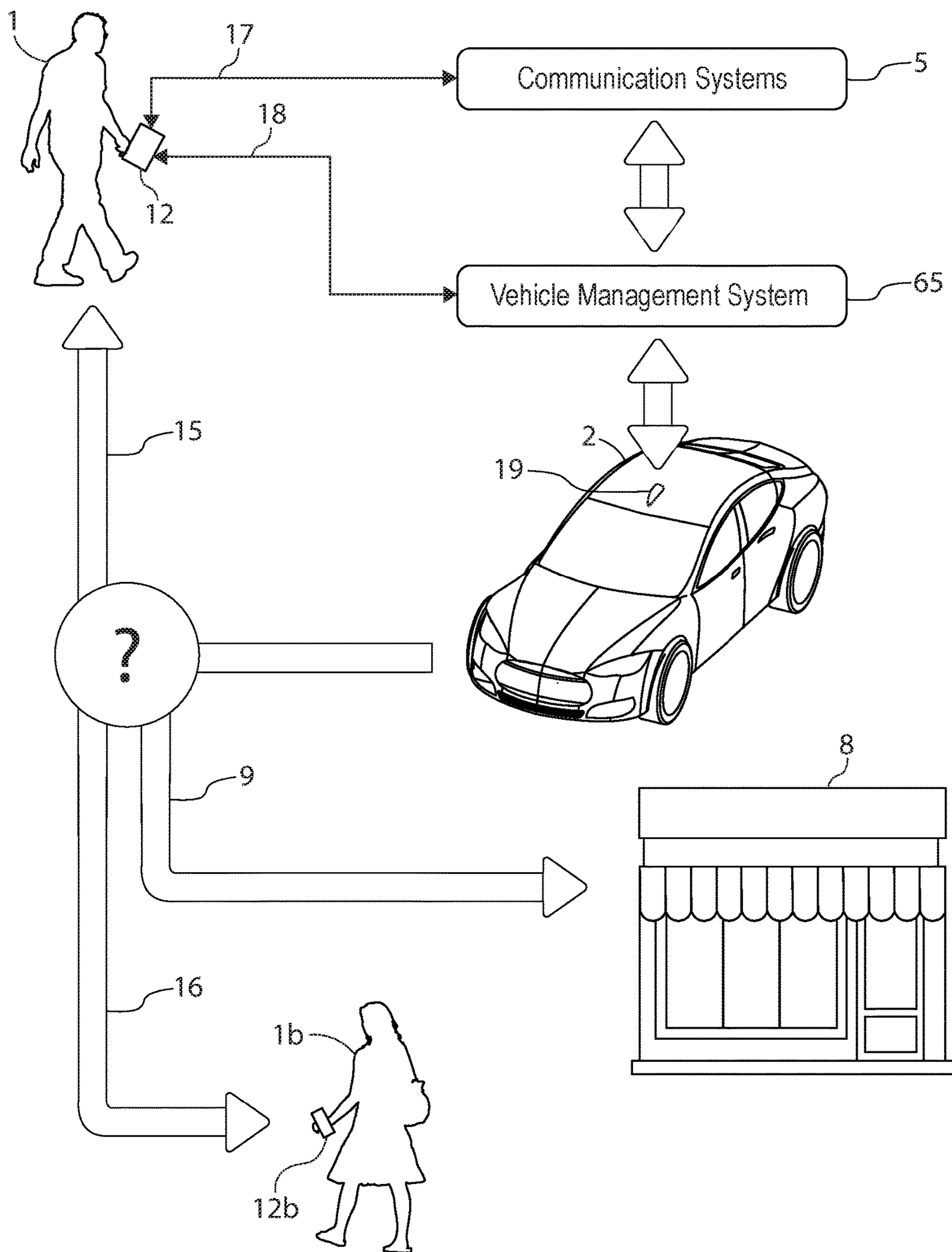


FIG. 1

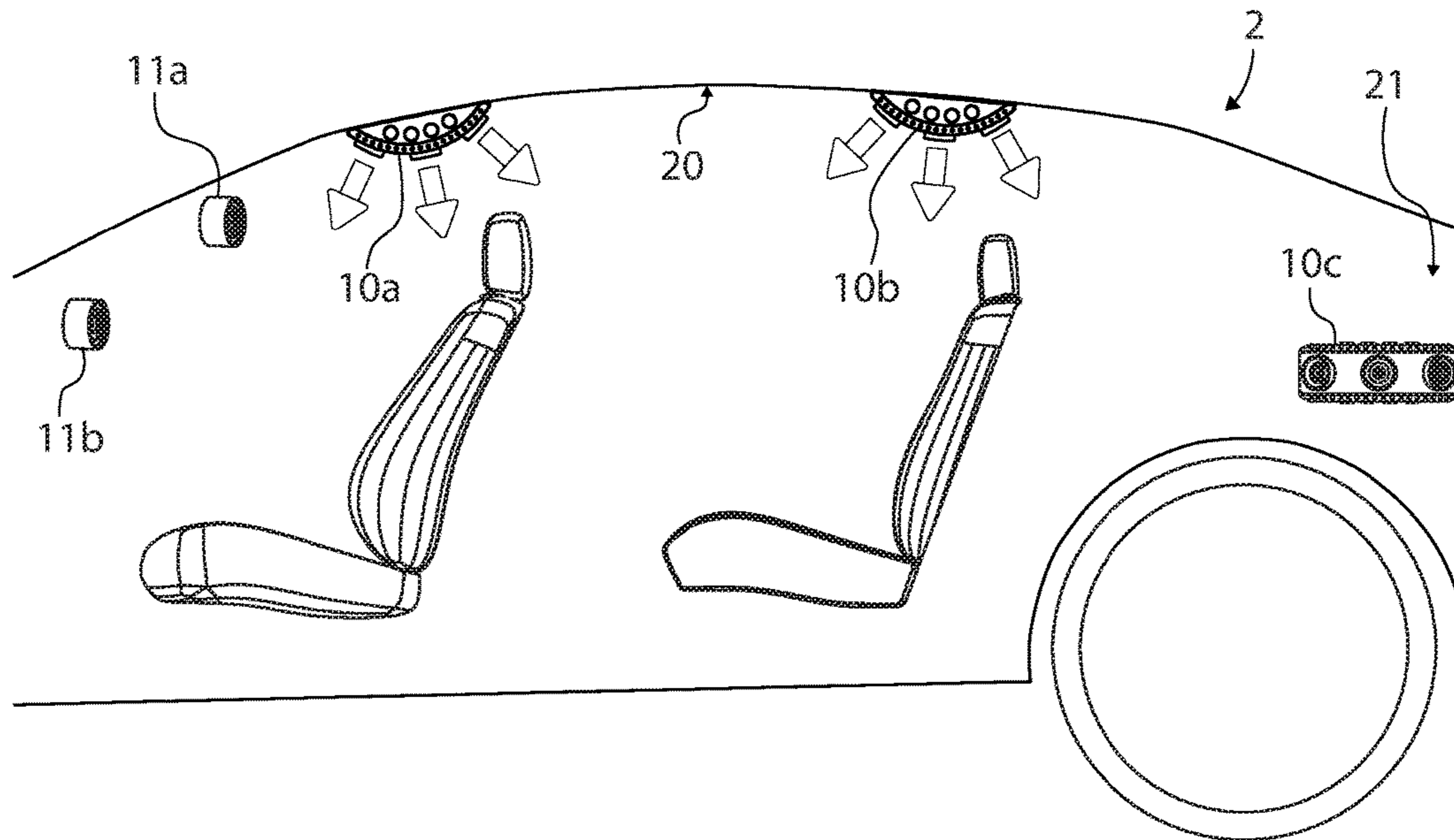


FIG. 2

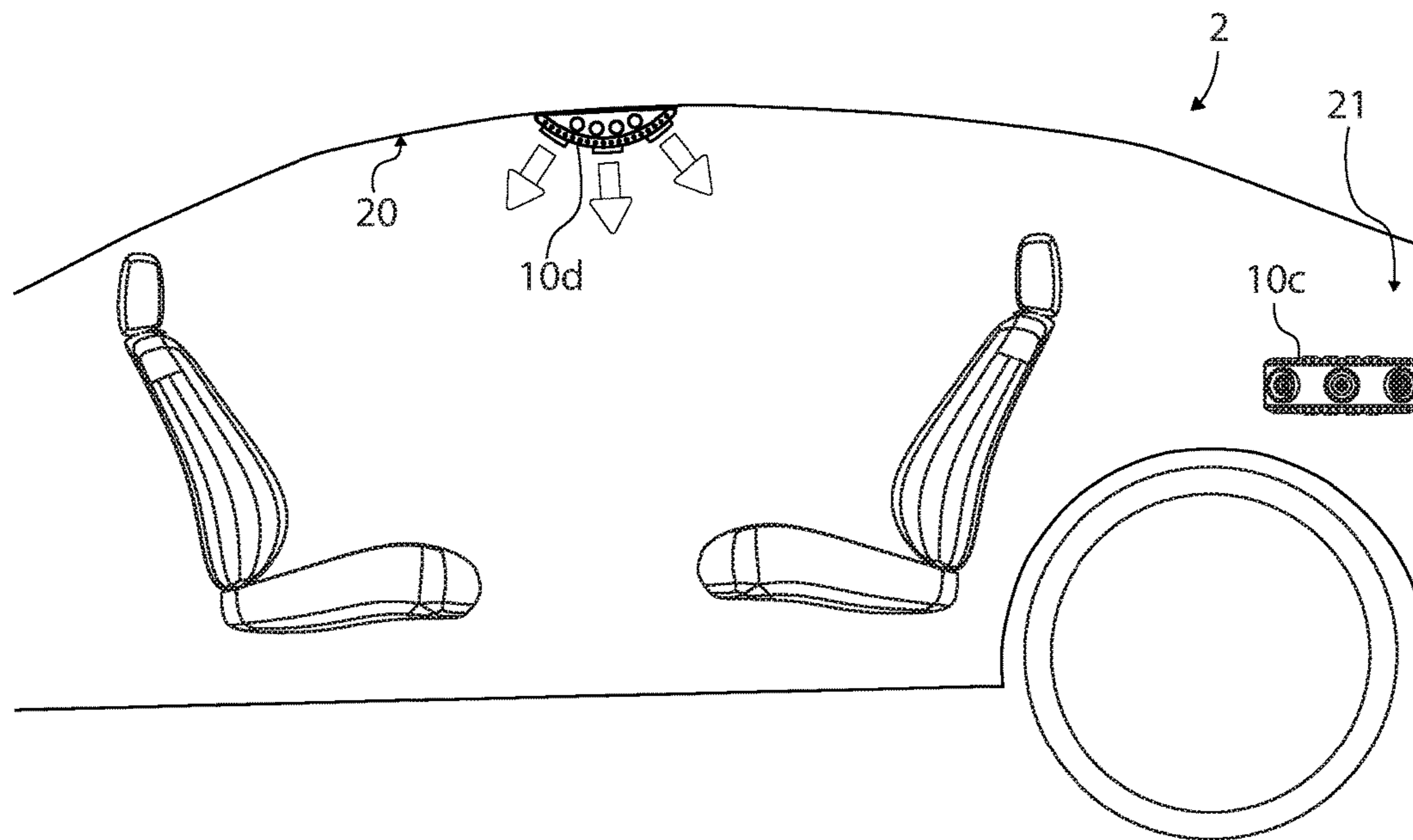


FIG. 3

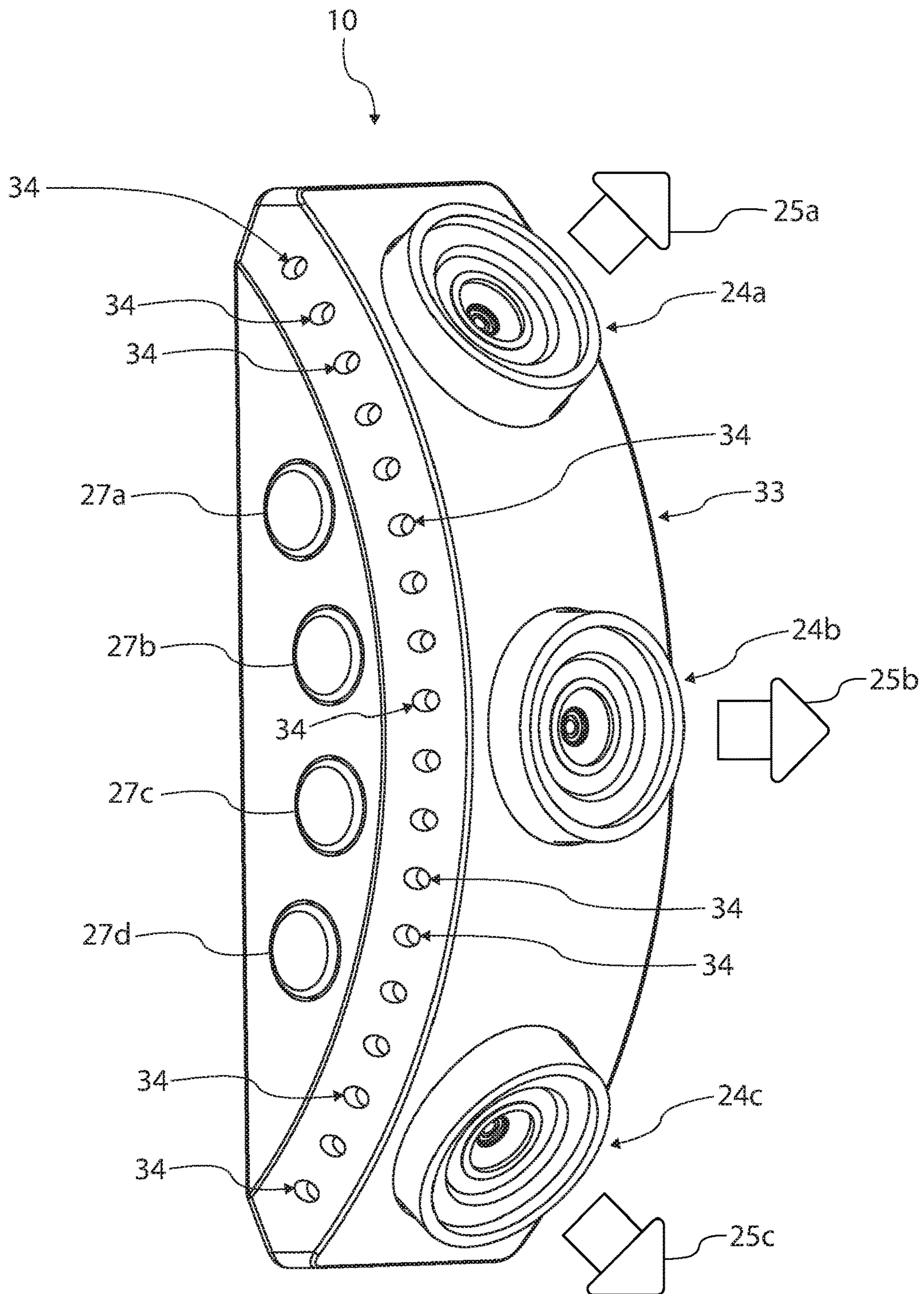


FIG. 4

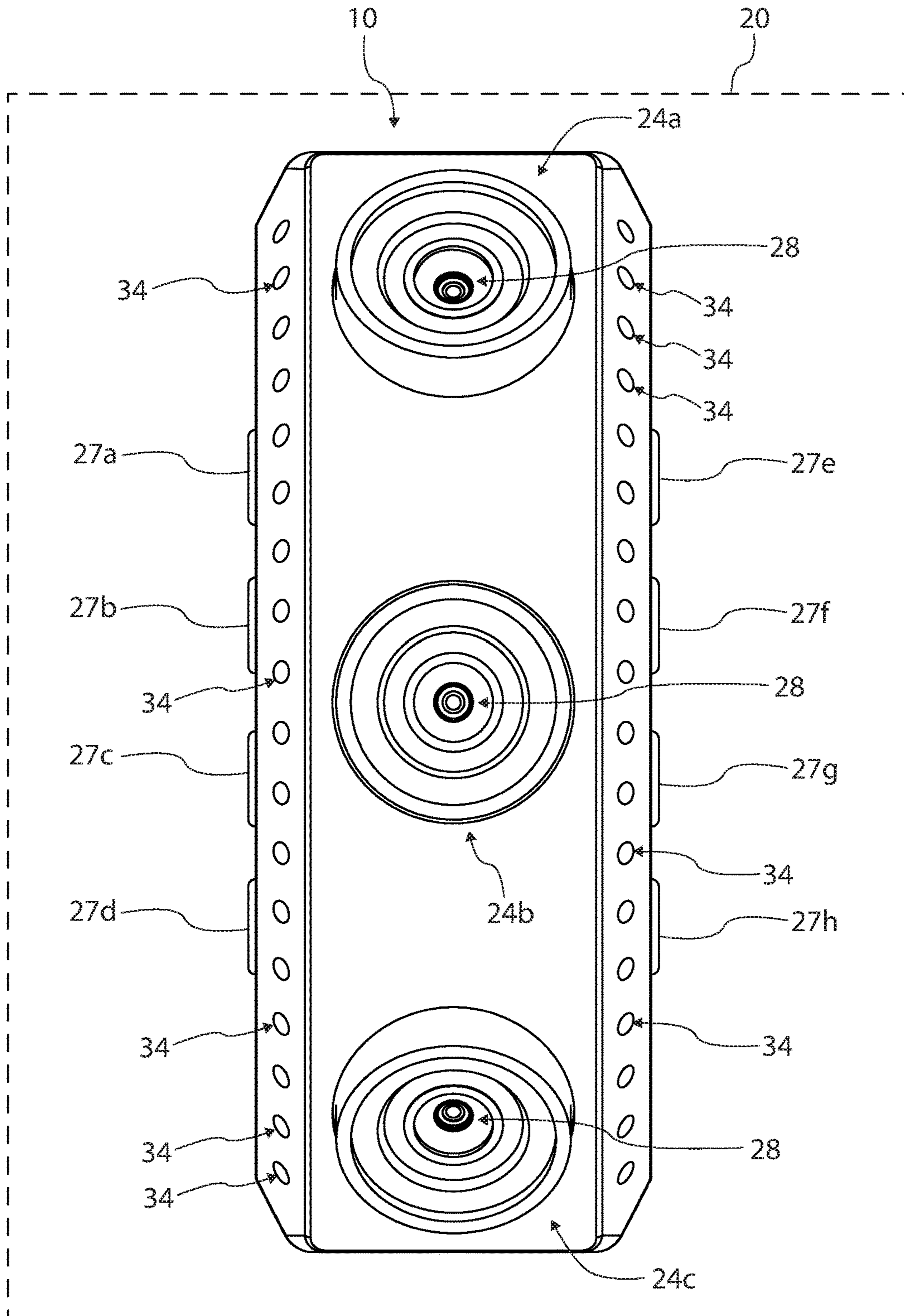


FIG. 5

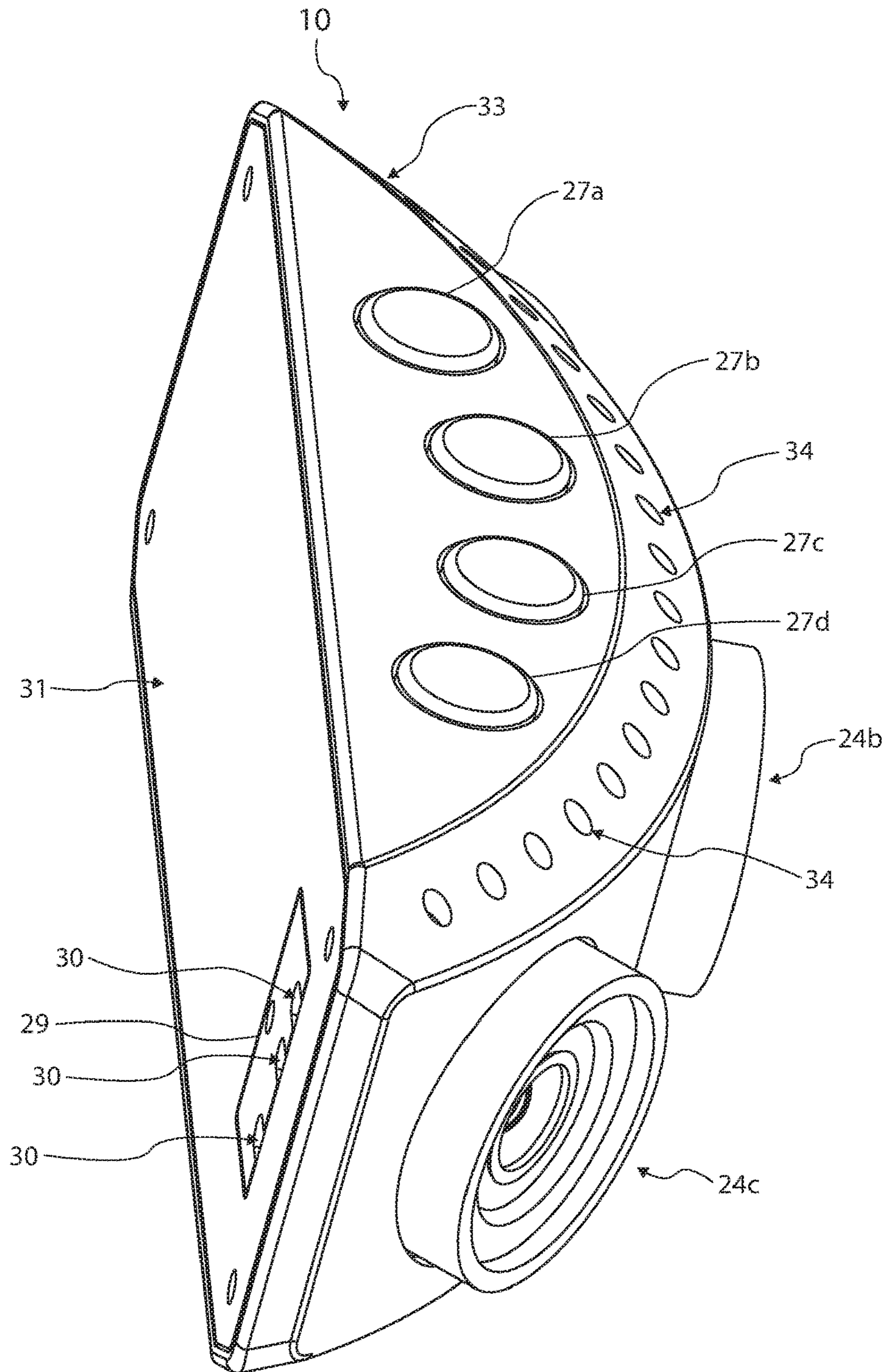


FIG. 6

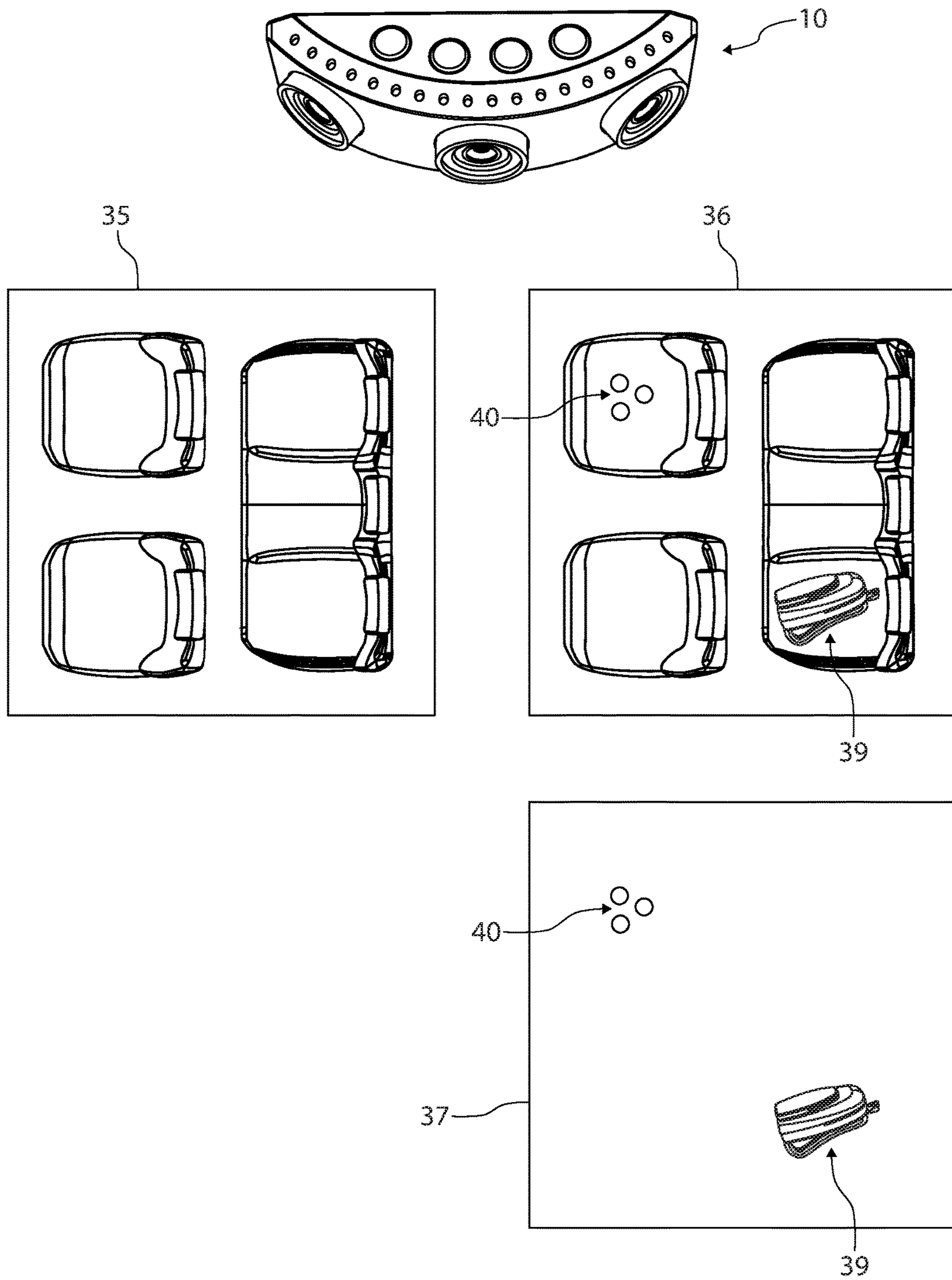


FIG. 7

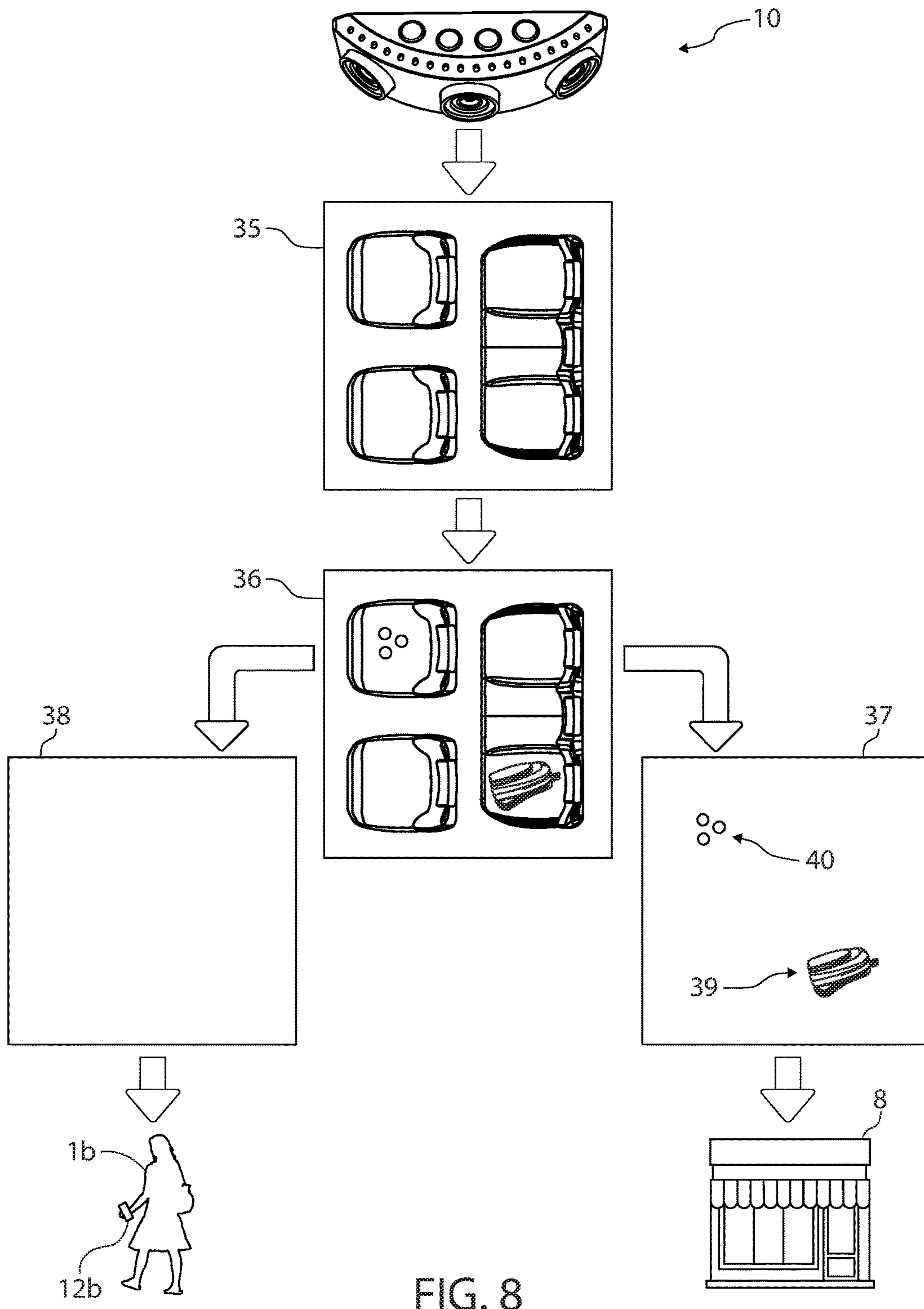


FIG. 8

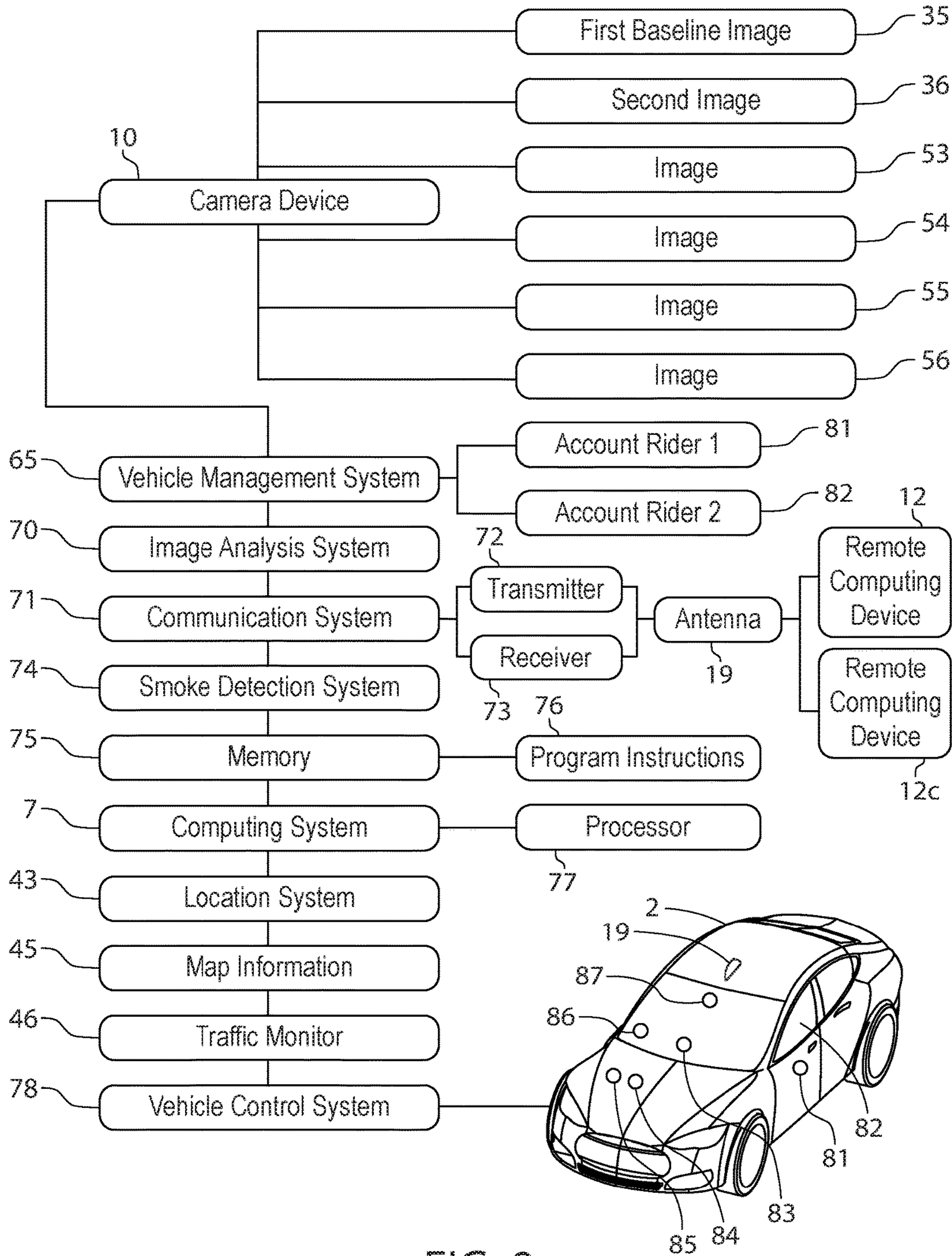


FIG. 9

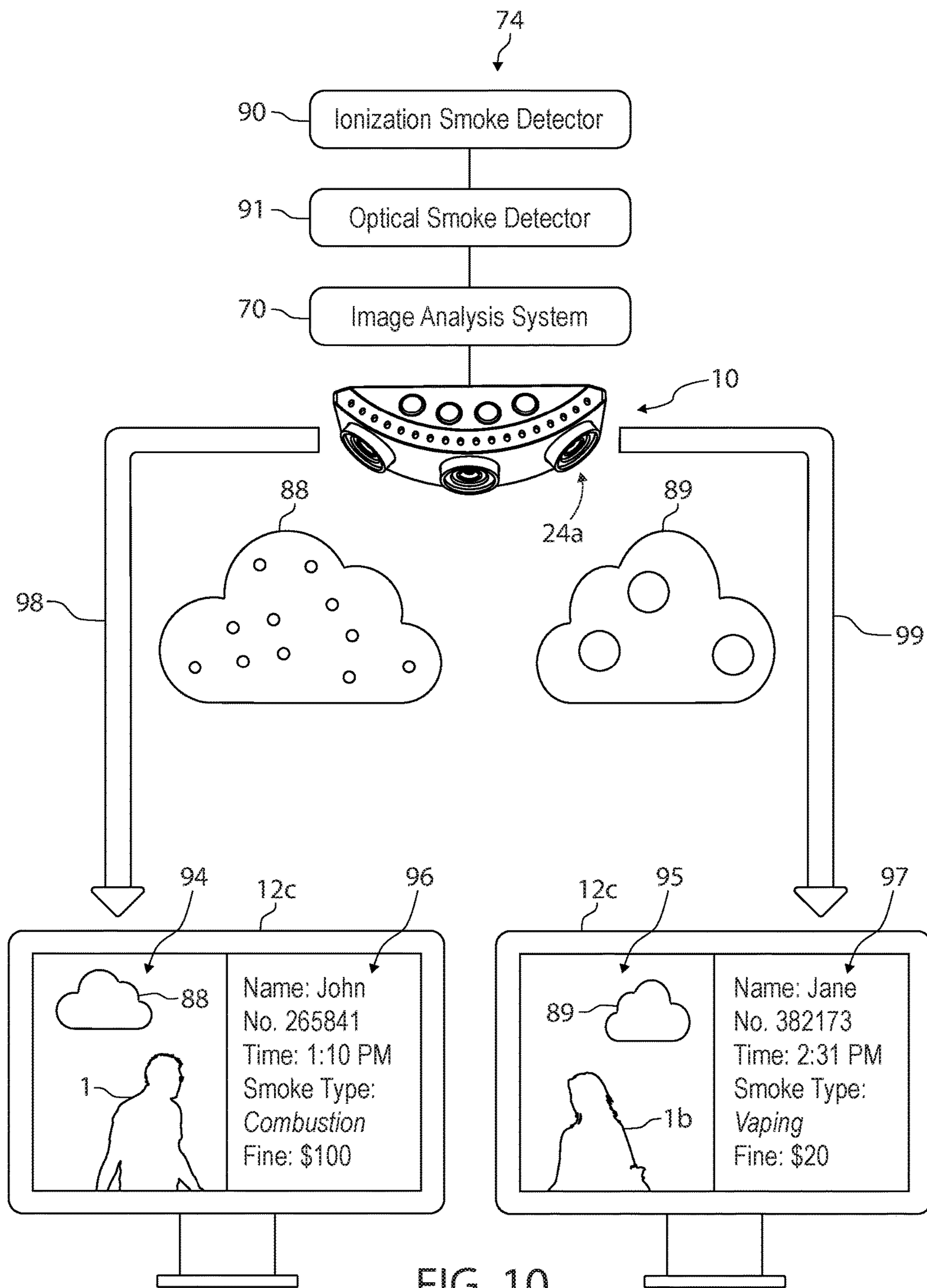


FIG. 10

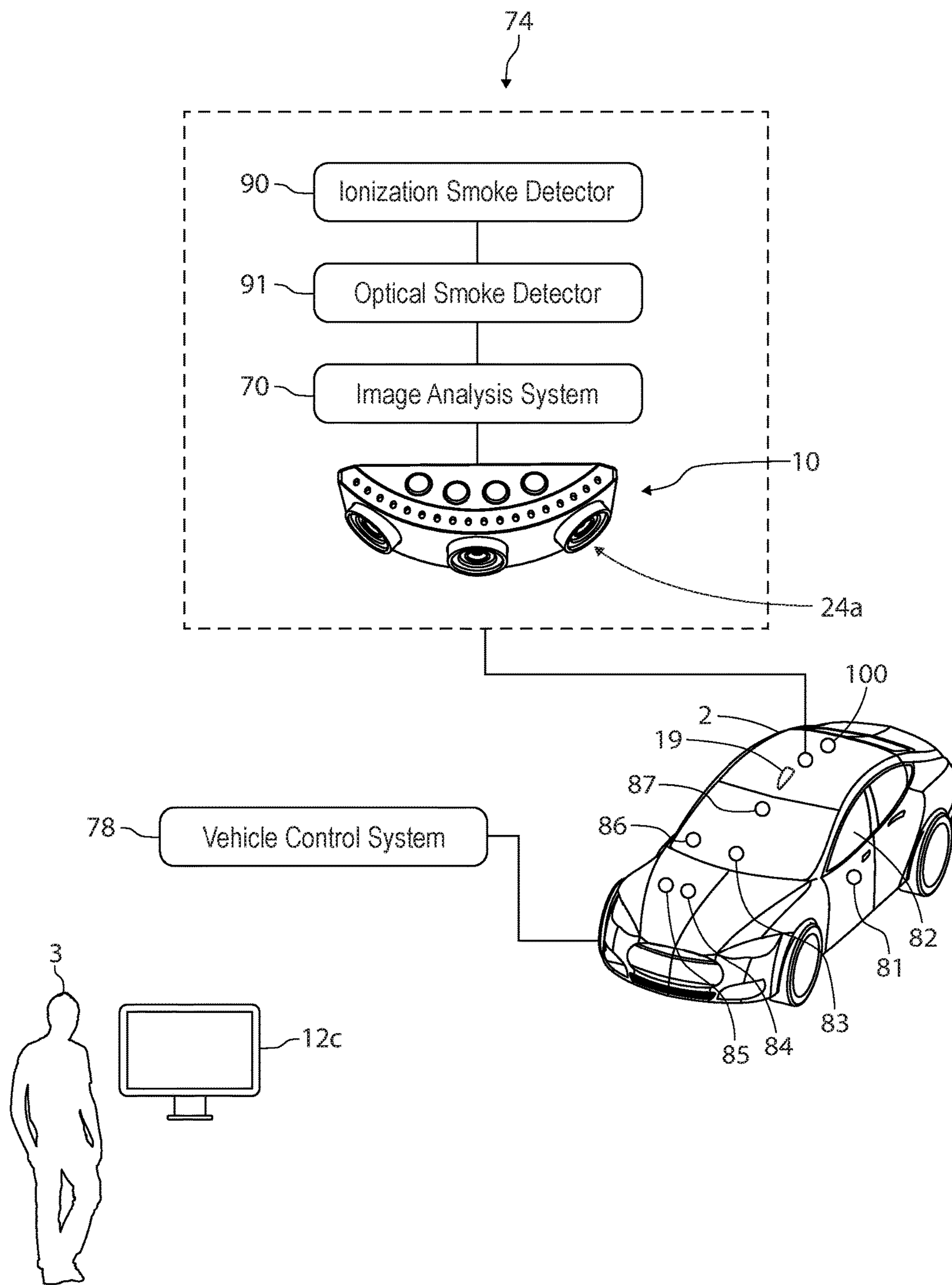


FIG. 11

SELF-DRIVING VEHICLE SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 16/134,190; filed Sep. 18, 2018; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 16/128,334; filed Sep. 11, 2018; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 15/863,903; filed Jan. 8, 2018; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 16/049,275; filed Jul. 30, 2018; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 15/181,413; filed Jun. 14, 2016; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 15/099,565; filed Apr. 14, 2016; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 15/248,910; filed Aug. 26, 2016; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

The entire contents of the following application are incorporated by reference herein: U.S. patent application Ser. No. 15/589,619; filed May 8, 2017; and entitled SELF-DRIVING VEHICLE SYSTEMS AND METHODS.

BACKGROUND

Field

Various embodiments disclosed herein relate to vehicles. Certain embodiments relate to self-driving vehicles.

Description of Related Art

Vehicles typically require a driver. These vehicles often can only perform actions when directly steered by the driver. However, self-driving vehicles are not reliant upon drivers and can perform actions based upon particular events. Self-driving vehicles can dramatically increase travel safety and convenience. As a result, there is a need for systems and methods that enable self-driving vehicles to perform actions based upon particular events.

SUMMARY

Self-driving vehicles will save tens of thousands of lives per year. The majority of vehicle-related deaths are caused by driver error. Tests have shown that self-driving vehicles nearly eliminate self-inflicted accidents (although they are not immune to accidents caused by human drivers of other vehicles). Self-driving vehicles have unlimited attention spans and can process complex sensor data nearly instantaneously. The ability of self-driving vehicles to save lives is

so impressive that society has a moral imperative to develop self-driving technology such that it can be widely adopted.

Self-driving vehicles also have the ability to dramatically save time and improve convenience in roadway travel. Specifically, self-driving vehicles have unlimited potential to learn and predict human behavior and perform actions accordingly. Some embodiments enable a self-driving vehicle to monitor human activity and predict when and where the human will be located and whether the human needs a ride from the self-driving vehicle. Self-driving vehicles will be able to perform such tasks with incredible efficacy and accuracy that will allow self-driving vehicles to proliferate at a much faster rate than would otherwise be the case.

Some embodiments comprise a maintenance system configured to be used with a self-driving vehicle. In some embodiments, maintenance systems comprise a camera system coupled to an interior of the vehicle. The camera system can be configured to take a picture of an item left behind by a first rider. Maintenance systems can comprise a vehicle management system configured to autonomously drive the vehicle to a first location to remove the item.

In some embodiments, the camera system comprises a first camera coupled to a ceiling of the vehicle and directed towards a first row of the vehicle, and the camera system comprises a second camera coupled to the ceiling of the vehicle and directed towards a second row of the vehicle.

In some embodiments, the camera system comprises a first camera coupled to a rear-view mirror of the vehicle and directed towards a first row of the vehicle, and the camera system comprises a second camera coupled to a ceiling of the vehicle and directed towards a second row of the vehicle.

In some embodiments, the camera system comprises a first camera located in a trunk area of the vehicle such that the first camera is configured to enable an image analysis system to determine if the item is left in the trunk area.

In some embodiments, the maintenance system comprises an image analysis system configured to detect the item left behind by comparing a first baseline image taken by the camera system of the interior of the vehicle to a second image taken by the camera system after the first baseline image.

In some embodiments, the vehicle management system is configured to automatically drive the vehicle to the first location to remove the item in response to the image analysis system detecting the item left by the first rider.

Some embodiments comprise a communication system configured to send a first wireless communication to a remote computing device associated with the first rider in response to the image analysis system detecting the item left behind by the first rider. The first wireless communication can be configured to notify the first rider that the item was left behind.

In some embodiments, the communication system is configured to send a second wireless communication comprising a third image of the item to the remote computing device in response to the image analysis system detecting the item left behind by the first rider. The third image can enable the rider to see the item on a display of her remote computing device.

In some embodiments, the vehicle management system is configured to receive an address of the first location from the remote computing device in response to the communication system sending the first wireless communication.

In some embodiments, the first location is an address at which the first rider has requested to pick up the item. The address can be the rider's current address. The address can

also be a location at which the rider is not currently located by at which the rider (or the rider's representative) plans to meet the vehicle (or another vehicle carrying the item) to retrieve the item.

In some embodiments, the communication system is configured to receive a third wireless communication from the remote computing device associated with the first rider in response to the communication system sending the first wireless communication. The third wireless communication can comprise instructions for shipping the item.

In some embodiments, the first location is a shipping location (such as a FedEx, UPS, or USPS facility) configured to remove the item from the vehicle and configured to ship the item according to the shipping instructions. The vehicle management system can be configured to enable removing the item from the vehicle once the vehicle is located at the shipping location.

In some embodiments, the vehicle management system is configured to receive the first location of a service area configured to clean the vehicle. The vehicle management system can be configured to drive the vehicle to the service area to remove the item in response to the image analysis system detecting the item left by the first rider.

Some embodiments comprise a third image taken by the camera system in response to the vehicle leaving the service area. Some embodiments comprise a communication system configured to send a first wireless communication comprising the third image to a remote computing device associated with a manager of the vehicle. The first wireless communication can be configured to enable the manager to verify that the item was removed from the vehicle.

Some embodiments comprise a third image taken by the camera system. The image analysis system can be configured to compare the third image to the second image to detect that the item was removed from the vehicle.

In some embodiments, the vehicle management system is configured to fine an account of the first rider in response to the image analysis system detecting the item left behind by the first rider.

In some embodiments, a communication system is configured to send a first wireless communication to a remote computing device associated with the first rider in response to the image analysis system detecting the item left behind by the first rider. The first wireless communication can comprise a third image taken by the camera system. The third image can be configured to show the item. The first wireless communication can be configured to ask the first rider if the item belongs to the first rider. The communication system can be configured to receive a second wireless communication from the remote computing device in response to the first wireless communication. The second wireless communication can be configured to inform the maintenance system that the first rider is an owner of the item. The maintenance system can comprise a memory configured to record that the first rider is the owner of the item.

In some embodiments, the maintenance system comprises a location detection system configured to receive the first location of a remote computing device associated with the first rider to enable the vehicle management system to autonomously drive the vehicle to the first location in response to an image analysis system detecting the item left behind by the first rider.

In some embodiments, the maintenance system comprises an image analysis system configured to detect the item left behind by comparing a first baseline image taken by the

camera system of the interior of the vehicle to a second image (of the interior) taken by the camera system after the first baseline image.

In some embodiments, the maintenance system comprises a communication system having an antenna, a transmitter, and a receiver. The communication system can be configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the image analysis system detecting the item left behind by the first rider.

In some embodiments, the first wireless communication is configured to notify the manager that the item was left behind. The communication system can be configured to send a second wireless communication comprising a third image of the item to the remote computing device in response to the image analysis system detecting the item left behind by the first rider.

In some embodiments, the vehicle management system is configured to receive a third wireless communication from the remote computing device in response to the communication system sending the first wireless communication. The third second wireless communication can be configured to instruct the vehicle management system to autonomously drive the vehicle to the first location to remove the item.

In some embodiments, the vehicle management system is configured to determine that the first rider has exited the vehicle. The vehicle management system can be configured to cause the camera system to take a first interior image of the interior of the vehicle in response to determining that the first rider has exited the vehicle.

In some embodiments, the maintenance system further comprises an image analysis system having at least one processor and a memory comprising program instructions (e.g., code modules configured to be executed by one or more computers) that when executed by the at least one processor are configured to cause the image analysis system to detect the item left behind by analyzing the first interior image taken by the camera system after the first rider has exited the vehicle. The first location can be a vehicle cleaning facility. The vehicle management system can be configured to drive the vehicle to the vehicle cleaning facility to remove the item in response to the image analysis system detecting the item.

In some embodiments, the vehicle management system comprises a first mode and a second mode. In the first mode, the vehicle management system can be configured to make the vehicle available to accept a pick-up request of a second rider. In the second mode, the vehicle management system can be configured to make the vehicle unavailable to accept the pick-up request. The vehicle management system can be configured to be in the second mode from a first time at which the image analysis system detects the item left behind. The vehicle management system can be configured to exit the second mode and enter the first mode in response to at least one of the item being removed, receiving an indication that the vehicle has been cleaned, and the vehicle leaving a vehicle cleaning station.

In some embodiments, the vehicle management system is configured to determine that the first rider has exited the vehicle in response to (1) receiving a location of a remote computing device associated with the first rider and determining that the location is not inside the vehicle, (2) failing to detect a direct wireless communication from the remote computing device to an antenna of the vehicle, (3) determining, by the image analysis system, that a second interior image does not show the first rider, and/or (4) determining,

by the image analysis system, that an infrared image of the interior of the vehicle does not show the first rider.

In some embodiments, the maintenance system comprises at least one processor and a memory comprising program instructions that when executed by the at least one processor cause the maintenance system to (1) compare a first baseline image taken by the camera system of the interior of the vehicle to a second image taken by the camera system after the first baseline image to detect the item left behind by the first rider, and/or (2) drive, by the vehicle management system, the vehicle to the first location to remove the item in response to the detecting the item. The program instructions can comprise code modules configured to be executed by one or more computers located in the vehicle and/or located away from the vehicle.

In some embodiments, the first location is a first vehicle cleaning facility. The program instructions can be configured to select the first vehicle cleaning facility based at least in part on determining a distance from the vehicle to the first vehicle cleaning facility and/or based at least in part on determining that the first vehicle cleaning facility is approved by a manager of the vehicle. The memory can comprise a list vehicle cleaning facilities that were approved by the manager of the vehicle. The program instructions can be configured to choose a cleaning facility that was previously approved by the manager and is located near the current location of the vehicle.

In some embodiments, the program instructions are configured to send a first wireless communication to a remote computing device associated with the first rider in response to detecting the item. The first wireless communication can comprise an image of the item. The program instructions can be configured to receive a second wireless communication from the remote computing device in response to sending the first wireless communication. The second wireless communication can comprise an instruction (e.g., from the first rider) to return the item. The program instructions can be configured to drive, by the vehicle management system, the vehicle to the first location in response to the instruction.

Some embodiments comprise a maintenance system configured to be used with a self-driving vehicle. A maintenance system can comprise a smoke detection system configured to detect smoke inside a cabin of the vehicle; a communication system configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the smoke detection system detecting the smoke; and/or a vehicle management system configured to autonomously drive the vehicle.

In some embodiments, a maintenance system comprises a memory having an identification of a first rider of the vehicle. The communication system can comprise an antenna, a transmitter, and/or a receiver. The communication system can be configured to send the identification of the first rider to the remote computing device of the manager in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, a maintenance system comprises a camera system coupled to an interior of the vehicle. The camera system can be configured to take a picture of a first rider smoking. The communication system can be configured to send the picture of the first rider smoking to the remote computing device.

In some embodiments, the camera system comprises a first camera directed towards a first row of the vehicle. The first camera can be configured to take the picture in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, the smoke detection system comprises a camera system and an image analysis system configured to detect the smoke inside the vehicle by comparing a first baseline image taken by the camera system of an interior of the vehicle to a second image taken by the camera system (of the interior of the vehicle) after the first baseline image.

In some embodiments, the smoke detection system comprises an ionization smoke detector configured to detect cigarette smoking. The smoke detection system can also comprise an optical smoke detector configured to detect electronic cigarette aerosol by analyzing a particle size of the aerosol and determining that the particle size is indicative of electronic cigarette use.

In some embodiments, the smoke detection system comprises at least one optical smoke detector configured to analyze a particle size of the smoke. The communication system is configured to send the first wireless communication identifying the smoke as an aerosol in response to the smoke detection system determining that the particle size is greater than a predetermined threshold. The communication system can be configured to send the first wireless communication identifying the smoke as cigarette smoking in response to the smoke detection system determining that the particle size is less than the predetermined threshold.

In some embodiments, a camera system is coupled to an interior of the vehicle. The camera system can be configured to take a picture of a first rider smoking. The communication system can be configured to send the picture of the first rider smoking to the remote computing device. The first wireless communication can be configured to enable the remote computing device to display the picture of the first rider smoking and to display an indication of whether the smoke is due to the aerosol or the cigarette smoking.

In some embodiments, the vehicle management system comprises a motor configured to roll down a window of the vehicle. The vehicle management system can be configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, the vehicle management system comprises a ventilation system having a fan to push air in the cabin. The fan can be located inside the dash of the vehicle such that the fan pushes air in the cabin by pushing air through a vent and into the cabin. The vehicle management system can be configured to automatically increase a rate at which the ventilation system pushes outside air into the cabin of the vehicle in response to the smoke detection system detecting the smoke inside the vehicle. In several embodiments, the rate is increased by increasing a rotational speed of the fan.

In some embodiments, the vehicle management system comprises a temperature management system having a thermometer and having at least one of an air conditioner, a heater, and a ventilation system having a fan to circulate air in the cabin. The fan can be located inside a vent inside the dash of the vehicle such that the fan is configured to circulate air in the cabin by pushing air out from a vent. The vehicle management system can be configured to at least one of increase and decrease an ambient temperature inside the cabin by at least ten degrees Fahrenheit in response to the smoke detection system detecting the smoke inside the vehicle to decrease a comfort level of a first rider.

In some embodiments, the vehicle management system is configured to decrease an ambient temperature inside the cabin by at least ten degrees Fahrenheit and/or by at least twenty degrees Fahrenheit in response to the smoke detec-

tion system detecting the smoke inside the vehicle to decrease a comfort level of a first rider. The vehicle management system can be configured to increase an ambient temperature inside the cabin by at least ten degrees Fahrenheit and/or by at least twenty degrees Fahrenheit in response to the smoke detection system detecting the smoke inside the vehicle to decrease a comfort level of a first rider.

In some embodiments, the vehicle management system is configured to determine a local speed limit and is configured to automatically reduce a speed of the vehicle below the local speed limit in response to the smoke detection system detecting the smoke inside the vehicle. Some embodiments include reducing the speed so much that the vehicle stops (e.g., such that the vehicle is parked). The vehicle management system can be configured to determine a suitable parking location in response to the smoke detection system detecting the smoke inside the vehicle, and the vehicle management system can be configured to park the vehicle in the parking location in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, the vehicle management system comprises a speaker. The speaker can be configured to emit audio commands instructing a first rider of the vehicle to cease smoking in order to cause the vehicle management system to increase the speed and/or start moving again after being stopped in a parking location.

In some embodiments, the vehicle is configured to drive a first rider to a destination selected by the first rider. The vehicle management system can be configured to cease driving towards the destination in response to the smoke detection system detecting the smoke inside the vehicle. The vehicle management system can be configured to continue driving towards the destination in response to the smoke detection system no longer detecting the smoke inside the vehicle.

In some embodiments, the vehicle management system is configured to fine an account of a first rider of the vehicle in response to the smoke detection system detecting the smoke inside the vehicle. The smoke detection system can be configured to analyze a particle size of the smoke to determine if the particle size is larger than a predetermined threshold. The vehicle management system can be configured to fine the account a first amount if the particle size is larger than the predetermined threshold. The vehicle management system can be configured to fine the account a second amount if the particle size is smaller than the predetermined threshold. The second amount can be larger than the first amount and/or at least 20 percent larger than the first amount. In some embodiments, the vehicle management system comprises a lighting system having at least one light coupled to an interior of the vehicle. The lighting system can be configured to illuminate at least one of a seat of the vehicle and a majority of the cabin. The vehicle management system can be configured to use the lighting system to illuminate at least one of the seat and the majority of the cabin in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, the vehicle management system comprises a speaker. The speaker can be configured to emit audio commands instructing a first rider of the vehicle to cease smoking. The vehicle management system can be configured to cease illuminating the majority of the cabin in response to the smoke detection system no longer detecting the smoke inside the vehicle.

In some embodiments, the vehicle management system is configured to receive a first location of a service area configured to clean the vehicle. The vehicle management

system can be configured to drive the vehicle to the service area in response to the smoke detection system detecting the smoke inside the vehicle.

In some embodiments, the smoke detection system is configured to detect the smoke emitted by a first rider while the vehicle is driving to a drop off location of the first rider. The vehicle management system can comprise a first mode and a second mode. In the first mode, the vehicle management system is configured to make the vehicle available to accept a pick-up request of a second rider. In the second mode, the vehicle management system is configured to make the vehicle unavailable to accept the pick-up request. The vehicle management system can be configured to enter the second mode in response to the smoke detection system detecting the smoke inside the vehicle. The vehicle management system can be configured to exit the second mode and enter the first mode in response to at least one of receiving an indication that the vehicle has been cleaned and the vehicle leaving a vehicle cleaning station.

In some embodiments, the vehicle management system comprises a ventilation system having a fan to push air in the cabin. The fan can be embedded in a vent channel of the dash or can be located in any other suitable location. The smoke detection system can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system can be configured to automatically increase a rate at which the ventilation system pushes outside air into the cabin in response to the smoke detection system detecting the smoke inside the vehicle. The vehicle management system can be configured to drive the vehicle to a service area configured to clean the vehicle in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system comprises a motor configured to roll down a window of the vehicle. The smoke detection system is configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system can be configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle. The vehicle management system can be configured to drive the vehicle to a service area configured to clean the vehicle in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system comprises at least one of a motor configured to roll down a window of the vehicle and a ventilation system having a fan to push air in the cabin. The smoke detection system can be configured to detect the smoke emitted by a first rider while the vehicle is driving to a drop off location of the first rider. The smoke detection system can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold.

In some embodiments, in response to the smoke detection system detecting the smoke inside the vehicle, the vehicle management system is configured to at least one of use the motor to automatically roll down the window and increase a rate at which the ventilation system pushes the air into the cabin.

In some embodiments, in response to determining that the particle size is larger than the predetermined threshold and after at least one of rolling down the window and increasing the rate, the vehicle management system is configured to make the vehicle available to pick up a second rider.

In some embodiments, in response to determining that the particle size is smaller than the predetermined threshold, the vehicle management system is configured to make the vehicle unavailable to pick up the second rider until after the vehicle management system has driven the vehicle to a service area configured to clean the vehicle.

In some embodiments, the vehicle management system comprises a motor configured to roll down a window of the vehicle and a rain sensor configured to detect an indication of rain on the vehicle. The smoke detection system can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system can be configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle and/or in response to the rain sensor not detecting the indication of the rain. The vehicle management system can be configured to drive the vehicle to a service area configured to clean the vehicle in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system comprises a motor configured to roll down a window of the vehicle and a rain sensor configured to detect an indication of rain on the vehicle. The vehicle management system can be configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle and in response to the rain sensor not detecting the indication of the rain.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages are described below with reference to the drawings, which are intended to illustrate, but not to limit, the invention. In the drawings, like reference characters denote corresponding features consistently throughout similar embodiments.

FIG. 1 illustrates a diagrammatic view that includes a self-driving vehicle configured to use a camera system, according to some embodiments.

FIG. 2 illustrates a side view of an interior of the self-driving vehicle with cameras located in several areas, according to some embodiments.

FIG. 3 illustrates a side view of an interior of the self-driving vehicle with seats facing each other, according to some embodiments.

FIG. 4 illustrates a perspective view of a camera device, according to some embodiments.

FIG. 5 illustrates a bottom view of the camera device, according to some embodiments.

FIG. 6 illustrates a perspective view of the camera device, according to some embodiments.

FIGS. 7 and 8 illustrate diagrammatic views regarding a camera system of a self-driving vehicle, according to some embodiments.

FIG. 9 illustrates a diagrammatic view that includes a self-driving vehicle, a camera system, and a smoke detection system, according to some embodiments.

FIGS. 10 and 11 illustrate diagrammatic views of a smoke detection system, according to some embodiments.

DETAILED DESCRIPTION

Although certain embodiments and examples are disclosed below, inventive subject matter extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses, and to modifications and equiva-

lents thereof. Thus, the scope of the claims appended hereto is not limited by any of the particular embodiments described below. For example, in any method or process disclosed herein, the acts or operations of the method or process may be performed in any suitable sequence and are not necessarily limited to any particular disclosed sequence. Various operations may be described as multiple discrete operations in turn, in a manner that may be helpful in understanding certain embodiments; however, the order of description should not be construed to imply that these operations are order dependent. Additionally, the structures, systems, and/or devices described herein may be embodied as integrated components or as separate components.

For purposes of comparing various embodiments, certain aspects and advantages of these embodiments are described. Not necessarily all such aspects or advantages are achieved by any particular embodiment. Thus, for example, various embodiments may be carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other aspects or advantages as may also be taught or suggested herein.

Self-driving vehicles will save tens of thousands of lives per year. The majority of vehicle-related deaths are caused by driver errors. Tests have shown that self-driving vehicles nearly eliminate self-inflicted accidents (although they are not immune to accidents caused by human drivers of other vehicles).

Self-driving vehicles typically have unlimited attention spans and can process complex sensor data nearly instantaneously. (Alphabet Inc. and Tesla Motors Inc. have built self-driving vehicles.) The ability of self-driving vehicles to save lives is so impressive that society has a moral imperative to develop self-driving technology such that it can be widely adopted.

Although self-driving vehicles will unlock many safety benefits, there are several barriers to rapid adoption of self-driving vehicles. Some of the embodiments described herein overcome several of these barriers.

Self-driving cars are sometimes referred to as autonomous cars, autonomous vehicles, driverless cars, and driverless vehicles. Various levels of “self-driving” behaviors are available to sense surrounding environments and navigate appropriately (e.g., without hitting objects, in a time-efficient manner). Levels of self-driving vehicles comprise Level 1 (Driver Assistance), Level 2 (Partial Automation), Level 3 (Conditional Automation), Level 4 (High Automation), and Level 5 (Full Automation). Of course, other levels and distinctions are possible. The National Highway Traffic Safety Administration has outlined various levels of self-driving vehicle automation based on information from the Society of Automotive Engineers.

Referring now primarily to FIG. 1, a vehicle management system 65 can be configured to govern the destinations of a self-driving vehicle 2. A first rider 1 can have a remote computing device 12 running software configured to enable the first rider 1 to request a ride from a ride service and/or from a particular vehicle.

The first rider 1 can open an “app” on an iPhone. The “app” can allow the first rider 1 to request a pick-up time and pick-up location.

The vehicle management system 65 can communicate with the remote computing device 12 of the first rider 1 directly (e.g., via radio communications such as Bluetooth) or indirectly via intermediary communication systems 5. Arrows 17, 18 indicate communication. (Many additional communication means and methods are compatible with the embodiments described herein.) An antenna 19 of the self-

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driving vehicle **2** can enable the vehicle management system **65** to communicate with remote computing devices **12**, **12b**.

A second rider **1b** may request a ride via a second remote computing device **12b**. In some cases, the vehicle management system **65** must choose between providing a ride to a first rider **1**, providing a ride to a second rider **1b**, and/or going to a first location **8** (e.g., to clean the vehicle prior to providing a ride to the first rider **1** and/or to the second rider **1b**). Arrow **15** indicates the self-driving vehicle **2** driving to the first rider **1** to give the first rider **1** a ride. Arrow **9** indicates the self-driving vehicle **2** driving to the first location **8** instead of driving to pick up the second rider **1b** right after dropping off the first rider **1**. Arrow **16** indicates the self-driving vehicle **2** eventually picking up the second rider **1b** (e.g., after the self-driving vehicle **2** is cleaned).

A person who owns a car is incentivized to keep the car clean because any mess the person leave in the car will be an annoyance to the person in the future. In contrast, a rider (who does not own the car) can leave a mess in the car without having to see the mess in the future. As a result, people who own self-driving vehicles **2** are motivated to keep the self-driving vehicles **2** clean while non-owning riders are more prone to leaving messes in self-driving vehicles **2**. Owners of vehicles **2** will not want to make their self-driving vehicles **2** available for riders **1**, **1b** if the owners are concerned that their vehicles **2** will return messy (after providing the rides). Thus, there is a need for systems that help maintain self-driving vehicles **2**.

An owner of a self-driving vehicle **2** will be reluctant to allow other riders to use the self-driving vehicle **2** (e.g., while the owner is at home or work) if the self-driving vehicle **2** will return messy. In addition, if a first rider **1** leaves a mess in the self-driving vehicle **2** (that is not cleaned up), subsequent riders will be unsatisfied with having to ride in a messy self-driving vehicle **2**.

One option is to clean the self-driving vehicle **2** between each rider. This option, however, is often cost-prohibitive. Unlike rental cars that are often rented for a day or more at a time, self-driving vehicles **2** can be rented for just a few minutes at a time. Driving the self-driving vehicle **2** to a cleaning station after each few minutes of rental time would require far too many unnecessary cleanings and unnecessary miles driven. Some embodiments described herein enable cleaning the self-driving vehicle **2** only when necessary and otherwise permitting the self-driving vehicle **2** to be used by a series of riders without taking the time to clean the self-driving vehicle **2**.

The self-driving vehicle **2** can include two modes. In the first mode, the self-driving vehicle **2** is considered clean and is available to accept a pick-up request. If the maintenance system detects that the self-driving vehicle **2** is unclean inside, then the system can enter a second mode in which the self-driving vehicle **2** is unavailable to accept a pick-up request and instead heads towards a cleaning facility. Once the self-driving vehicle **2** is clean, the system can enter the first mode again. As a result, the self-driving vehicle **2** may drop off the first rider **1**, detect that the self-driving vehicle **2** has an item left behind by the first rider **1**, and then instead of going to pick up the second rider **1b**, can go to a cleaning facility. (Another self-driving vehicle can pick up the second rider **1b** or the second rider **1b** can wait for the self-driving vehicle **2** to be cleaned and then can receive a ride from the self-driving vehicle **2**.)

The vehicle management system **65** can be a portion of the self-driving vehicle **2**. Communication between the vehicle **2** and the vehicle management system **65** can occur

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via electrical wires that couple the vehicle management system **65** to other portions of the vehicle **2**.

In some embodiments, the vehicle management system **65** is located remotely relative to the self-driving vehicle **2**. Communication between the vehicle **2** and the vehicle management system **65** can occur via wireless communications that travel over intermediary communication systems **5**.

In some embodiments, intermediary communication systems **5** are used to perform each step. Intermediary communication systems **5** can comprise wireless networks, Wi-Fi routers, Bluetooth systems, cellular networks, telephone networks, Internet systems, servers, cloud computing, remotely located computers, satellite systems, communication systems, and any other suitable means of enabling communication between the various components of embodiments described herein and/or incorporated by reference.

The communicative coupling between the remote computing device **12** and the vehicle management system **65** can be via intermediary communication systems **5**. In other words, intermediary communication systems **5** can communicatively couple the remote computing device **12** and the vehicle management system **65**. This communicative coupling may be via intermittent wireless communications. For example, the vehicle management system **65** may send a wireless message to the remote computing device **12** periodically (e.g., every 10 seconds, every 60 seconds, every 10 minutes). As used herein, "periodically" does not imply that every period has the same duration. In some embodiments, the communicative coupling between the self-driving vehicle **2** and the vehicle management system **65** is via intermediary communication systems **5**.

Some embodiments include methods of using the vehicle management system **65** to operate the self-driving vehicle **2**. The vehicle management system **65** is configured to be communicatively coupled with a remote computing device **12**, which is configured to operate software, such as an iPhone application or an Android application adapted to enable a user to control behaviors of the self-driving vehicle **2**. Behaviors can include actions and non-actions of the self-driving vehicle **2**, such as picking up the user at a location, picking up the user at a time based on a schedule of the user or a time based on past pick-up times, remaining idle, driving to a residence of the user, pulling out of a garage, parking the vehicle, getting gas, charging the vehicle, and the like.

Referring now primarily to FIG. **2**, the maintenance system can comprise a camera system having one or more camera devices **10a**, **10b**, **10c**, **10d**, **11a**, **11b**. The camera devices **10a**, **10b**, **10c**, **10d**, **11a**, **11b** can include any of the features and capabilities described in the context of the camera device **10**.

Camera devices **10a**, **10b** can be coupled to a ceiling **20** of the self-driving vehicle **2** such that they include cameras directed towards the first row of seats and/or towards the second row of seats. Camera devices **10c** can be placed in a trunk area of the self-driving vehicle **2** (e.g., to enable taking pictures and/or videos of items left in the trunk area).

A camera device **11a** can be integrated into the rear-view mirror of the self-driving vehicle **2**. A camera device **11b** can be integrated into the dash of the self-driving vehicle **2**. Camera devices **10a**, **10b**, **10c**, **11a**, **11b** can be placed in any area of the self-driving vehicle **2**.

As illustrated in FIG. **3**, the first and second rows of seats can face towards each other to create a more social riding experience. A camera device **10d** can be coupled to an

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interior of the self-driving vehicle 2. As illustrated in FIG. 3, the camera device 10d is coupled to the ceiling 20 of the self-driving vehicle 2.

FIG. 4 illustrates a perspective view of a camera device. FIG. 5 illustrates a bottom view of the camera device 10 coupled to a ceiling 20 of the self-driving vehicle 2. FIG. 6 illustrates a perspective view of the camera device 10 with the ceiling 20 hidden to show a top side of the camera device 10. (The top side is configured to face towards the ceiling 20 of the self-driving vehicle 2.)

The camera device 10 can include multiple cameras 24a, 24b, 24c. A first camera 24a can be directed in a first direction 25a (e.g., towards a front row of seats in the self-driving vehicle 2). A second camera 24b can be directed in a second direction 25b (e.g., towards a middle row of seats in the self-driving vehicle 2). A third camera 24c can be directed in a third direction 25c (e.g., towards a third row of seats in the self-driving vehicle 2).

Each camera 24a, 24b, 24c can include a wide-angle lens 28 to provide a wider field of view, which can be particularly helpful in the small confines of the self-driving vehicle 2. The cameras 24a, 24b, 24c can be high-resolution cameras with auto-focus.

The camera device 10 can comprise a rider detection system, a communication module (with can include an antenna, a transmitter, and a receiver), a printed circuit board populated with integrated circuits and other electrical components, an image analysis system, a battery, a power management system, a microphone, a speaker, a memory with software configured to carry out the features described herein, and lights configured to illuminate the interior of the self-driving vehicle 2.

The camera device 10 can comprise a smoke detector configured to detect if a rider is smoking (e.g., cigarettes, vaping) inside the self-driving vehicle 2. Holes 34 enable the smoke to enter the camera device 10 to enable the smoke detector to detect the smoke. Not all the holes 34 are labeled to increase the clarity of other features.

The camera device 10 includes buttons that can be configured to enable the rider to interact physically with the camera device. A first button 27a is configured to summon emergency responders in response to the rider pressing the button 27a. The camera device 10 can call “911” and can provide the GPS location of the self-driving vehicle 2 to the emergency responders.

A second button 27b is configured to call a virtual assistant (or a live human assistant) in response to the rider pressing the button 27b. The assistant can be configured to answer the rider’s questions. The virtual assistant can use Apple’s “Siri” technology or Amazon’s “Alexa” technology.

Pressing a third button 27c can notify the maintenance system that the interior of the self-driving vehicle 2 needs to be cleaned. Pressing a fourth button 27d can notify the maintenance system that the exterior of the self-driving vehicle 2 needs to be cleaned.

The camera device 10 can include an outer housing 33 (e.g., molded from plastic) that snaps onto a molded plastic base plate 31 that is coupled to the ceiling 20 by screws. A hatch 29 can be removed to enable plugging cables into the camera device 10. The cables can provide electrical power from the self-driving vehicle 2 to the camera device 10. The cables can also communicatively couple the camera device 10 to other portions of the self-driving vehicle 2 that communicatively couple the self-driving vehicle 2 to the vehicle management system 65. The cables can exit through holes 30 in the hatch 29. The camera device 10 can be

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coupled by wires or wirelessly communicatively coupled to the other elements described herein and/or incorporated by reference.

The vehicle management system 65 can be wirelessly communicatively coupled to the self-driving vehicle 2 via intermediary communication systems 5. The remote computing device 12 can be wirelessly communicatively coupled to the vehicle management system 65 via intermediary communication systems 5. Intermediary communication systems 5 can comprise wireless networks, cellular networks, telephone networks, Internet systems, servers, cloud computing, remotely located computers, radio communication systems, satellite systems, communication systems, and any other suitable means of enabling wired and/or wireless communication between the remote computing device 12, the vehicle management system 65, and/or the self-driving vehicle 2.

In embodiments that include elements such as sending information or otherwise communicating, the remote computing device 12, the vehicle management system 65, and the self-driving vehicle 2 can do these elements by using intermediary communication systems 5. For example, the remote computing device 12, the vehicle management system 65, and the self-driving vehicle 2 may send wireless communications and/or receive wireless communications via intermediary communication systems 5, which can serve as a communication bridge between the remote computing device 12, the vehicle management system 65, and the self-driving vehicle 2.

FIG. 7 illustrates a diagrammatic view of the camera device 10 and various images. The camera device 10 can take a first baseline image 35 (e.g., prior to the first rider 1 entering the self-driving vehicle 2). The camera device 10 can take a second image 36 in response to the first rider 1 exiting the self-driving vehicle 2. An image analysis system 70 can subtract the first baseline image 35 from the second image 36 to determine what features are in the second 36 but not in the first baseline image 35.

As shown in the subtraction result image 37, the first rider 1 left a valuable item 39 behind in the self-driving vehicle 2 and also left trash 40 behind in the self-driving vehicle 2. The system can send a picture of the valuable item 39 (e.g., a backpack or purse) to the first rider 1 to determine if the first rider 1 wants the system to return the valuable item 39 to the first rider 1. The system can remove the valuable item 39 prior to picking up a second rider 1b (to prevent the second rider from stealing the valuable item 39. In some embodiments, the system places the valuable item 39 in the trunk (and locks the trunk) prior to picking up the second rider 1b.

The system can determine the self-driving vehicle 2 needs to be cleaned prior to picking up the second rider 1b in response to detecting the trash 40.

Some embodiments use machine vision to detect the items 39, 40 left behind by analyzing the second image 36 without analyzing or needing the first baseline image 35. For example, software can be configured to detect that a backpack has been left in the self-driving vehicle 2 even if no baseline image 35 is available. In some cases, the first baseline image 35 can increase the accuracy and reliability of the system (e.g., by reducing false positives and false negatives).

Machine vision can recognize that shapes or even colors are indicative of an item not being part of the vehicle 2 (and thus the item is likely something left behind by a rider).

Machine vision can recognize common shapes (e.g., a backpack, a purse, a laptop, a coffee mug, a fast-food bag, a person, a dog).

FIG. 8 illustrates a diagrammatic view of the system deciding to pick up a second rider **1b** or deciding to go to a first location **8** (e.g., to remove an item left behind by a first rider **1**). The system can detect items **39**, **40** left behind by analyzing the second image **36** to detect things that should not be in the self-driving vehicle **2** after a rider **1** has left the self-driving vehicle **2**.

The system can detect items **39**, **40** left behind by comparing the second image **36** to a baseline image **35** (of items that should be located in the vehicle **2**). If the system detects items **39**, **40** (e.g., as illustrated in image **37**), then the system can send the self-driving vehicle **2** to the first location **8**. If the system does not detect any items left behind (e.g., as illustrated in image **38**), then the system can pick up the second rider **1b**.

FIG. 9 illustrates some of the elements of the maintenance system. Each of the elements illustrated in FIG. 9 is optional and is not necessarily present in each embodiment.

The maintenance system can include a camera device **10**, which can include memory **75** having many images **35**, **36**, **53**, **54**, **55**, **56** taken by the camera device **10**. The camera device **10** can be communicatively coupled to a vehicle management system **65**.

The vehicle management system **65** can be communicatively coupled to an image analysis system **70**, a communication system **71**, a smoke detection system **74**, a memory **75** having program instructions **76**, computing systems **7** having processors **77**, a location system **43**, map information **45** configured to help the vehicle **2** navigate to destinations, a traffic monitoring system **46** configured to receive up-to-date traffic information to enable the vehicle management system **65** to choose optimal routes to destinations, and a vehicle control system **78**.

The vehicle control system **78** is configured to steer, brake, and accelerate the vehicle **2**. The vehicle control system **78** is also configured to detect roads and obstacles on the roads.

The location system **43** is configured to receive a location of the remote computing device **12** associated with the first rider **1** and is configured to receive a location of the remote computing device **12b** associated with the second rider **1b**. The remote computing devices **12**, **12b** can send GPS, indoor location information, and/or other location information to the location system **43** to help the vehicle management system **65** determine where to pick up the rider **1**, **1b** and/or determine where to drop off an item left behind by a rider **1**, **1b**.

A user of a remote computing device can complete a number of steps to associate the remote computing device with herself. For example, Apple Inc. makes iPhones, Apple Watches, iPads, laptop computers, and other remote computing devices. A user can associate the iPhone, Apple Watch, iPad, laptop computer, or other remote computing device made by Apple Inc. by (1) turning on the device, (2) using the “Quick Start” option if the user has another device running iOS or selecting the “Set Up Manually” option, (3) activating the device and choosing a Wi-Fi network, (4) setting up “Face ID” and creating a password, and (5) signing in with an “Apple ID.” Of course, other remote computing devices use other methods to associate a remote computing device with a particular user.

In some cases, a remote computing device is associated with a user simply because the remote computing device is in the user’s possession.

The communication system **71** can include a transmitter **72**, a receiver **73**, and an antenna **19**. The antenna **19** can communicatively couple the vehicle management system **65** to remote computing devices **12**, **12b** of riders **1**, **1b**. The antenna **19** can communicatively couple the vehicle management system **65** to remote computing devices **12c** of a manager of the vehicle **2**.

The vehicle management system **65** can be communicatively coupled to an account **81** of a rider **1** to enable the system to fine the rider **1** for leaving items **39**, **40** in the vehicle **2**. The fine can be a dollar amount (e.g., \$20) such as a trash **40** removal fee or a fee to return a valuable item **39** to a rider **1**.

Some embodiments comprise a maintenance system configured to be used with a self-driving vehicle **2**. In some embodiments, maintenance systems comprise a camera system coupled to an interior of the vehicle **2**. The camera system can be configured to take a picture of an item left behind by a first rider. A maintenance system can comprise a vehicle management system configured to autonomously drive the vehicle **2** to a first location **8** to remove the item.

As used herein, a self-driving vehicle **2** can “autonomously drive” if the vehicle **2** is steering itself even if a person is providing input regarding navigation of the vehicle **2**.

As used herein, a still image and a video can both be types of pictures. As used herein, a still image and a video can both be types of images.

In some embodiments, the camera system comprises a first camera coupled to a ceiling of the vehicle **2** and directed towards a first row of the vehicle **2**, and the camera system comprises a second camera coupled to the ceiling of the vehicle **2** and directed towards a second row of the vehicle **2**. (The first camera can be directed towards a first row if an image taken by the camera shows the first row. The second camera can be directed towards a second row if an image taken by the camera shows the second row.)

In some embodiments, the camera system comprises a first camera coupled to a rear-view mirror of the vehicle **2** and directed towards a first row of the vehicle **2**, and the camera system comprises a second camera coupled to a ceiling of the vehicle **2** and directed towards a second row of the vehicle **2**.

In some embodiments, the camera system comprises a first camera located in a trunk area of the vehicle **2** such that the first camera is configured to enable an image analysis system **70** to determine if the item is left in the trunk area.

In some embodiments, the maintenance system comprises an image analysis system **70** configured to detect the item left behind by comparing a first baseline image **35** taken by the camera system of the interior of the vehicle **2** to a second image **36** taken by the camera system after the first baseline image **35**. Some embodiments comprise determining that the item is present in the second image **36** but not present in the first baseline image **35**.

In some embodiments, the vehicle management system is configured to automatically drive the vehicle **2** to the first location **8** to remove the item in response to the image analysis system **70** detecting the item left by the first rider.

Some embodiments comprise a communication system **71** configured to send a first wireless communication to a remote computing device **12** associated with the first rider in response to the image analysis system **70** detecting the item left behind by the first rider. The first wireless communication can be configured to notify the first rider that the item was left behind.

The communication system 71 can be configured to send the first wireless communication to a remote computing device 12 directly (e.g., via radio communications) or indirectly (e.g., via intermediary communication systems 5).

In some embodiments, the communication system 71 is configured to send a second wireless communication comprising a third image 53 of the item to the remote computing device 12 in response to the image analysis system 70 detecting the item left behind by the first rider. The third image 53 can enable the rider to see the item on a display of her remote computing device 12.

In some embodiments, the vehicle management system is configured to receive an address of the first location 8 from the remote computing device 12 in response to the communication system 71 sending the first wireless communication. The vehicle management system can be configured to receive the address from the remote computing device directly or indirectly.

As used herein, “address” is used broadly and is not limited to a street address. An address can be a Global Positioning System (“GPS”) location and can be any other location indicator. An address can be an indoor location (e.g., a location inside a large shopping center or apartment complex).

In some embodiments, the first location 8 is an address at which the first rider has requested to pick up the item. The address can be the rider’s current address. The address can also be a location at which the rider is not currently located by at which the rider (or the rider’s representative) plans to meet the vehicle 2 (or another vehicle 2 carrying the item) to retrieve the item.

In some embodiments, the communication system 71 is configured to receive a third wireless communication from the remote computing device 12 associated with the first rider in response to the communication system 71 sending the first wireless communication. The third wireless communication can comprise instructions for shipping the item. The instructions can comprise an address to which the system should ship the item. The instructions can comprise a manner in which the item should be shipped.

In some embodiments, the first location 8 is a shipping location (such as a FedEx, UPS, or USPS facility) configured to remove the item from the vehicle 2 and configured to ship the item according to the shipping instructions. The vehicle management system can be configured to enable removing the item from the vehicle 2 once the vehicle 2 is located at the shipping location. The vehicle 2 can unlock a door to enable removing the item. The vehicle 2 can send a smaller, short-range delivery robot to deliver the item to the shipping location.

In some embodiments, the vehicle management system is configured to receive the first location 8 of a service area configured to clean the vehicle 2. The vehicle management system can be configured to drive the vehicle 2 to the service area to remove the item in response to the image analysis system 70 detecting the item left by the first rider.

Some embodiments comprise a third image 54 taken by the camera system in response to the vehicle 2 leaving the service area. Some embodiments comprise a communication system 71 configured to send a first wireless communication comprising the third image 54 to a remote computing device 12c associated with a manager of the vehicle 2. The first wireless communication can be configured to enable the manager to verify that the item was removed from the vehicle 2.

Some embodiments comprise a third image 56 taken by the camera system. The image analysis system 70 can be

configured to compare the third image 56 to the second image 36 to detect that the item was removed from the vehicle 2.

In some embodiments, the vehicle management system is configured to fine an account of the first rider in response to the image analysis system 70 detecting the item left behind by the first rider. The fine can be a sum imposed as a punishment for leaving the item.

In some embodiments, a communication system 71 is configured to send a first wireless communication to a remote computing device 12 associated with the first rider in response to the image analysis system 70 detecting the item left behind by the first rider. The communication system 71 can be configured to send the first wireless communication to a remote computing device 12 directly (e.g., via radio communications) or indirectly (e.g., via intermediary communication systems 5).

The first wireless communication can comprise a third image 53 taken by the camera system. The third image 53 can be configured to show the item. The first wireless communication can be configured to ask the first rider if the item belongs to the first rider. The communication system 71 can be configured to receive a second wireless communication from the remote computing device 12 in response to the first wireless communication. The second wireless communication can be configured to inform the maintenance system that the first rider is an owner of the item. The maintenance system can comprise a memory configured to record that the first rider is the owner of the item.

In some embodiments, the system is configured to automatically drive the vehicle 2 to the rider’s current location (e.g., a GPS location).

In some embodiments, the maintenance system comprises a location detection system 43 configured to receive the first location 8 of a remote computing device 12 associated with the first rider to enable the vehicle management system to autonomously drive the vehicle 2 to the first location 8 in response to an image analysis system 70 detecting the item left by the first rider. The image analysis system 70 can be a part of the camera system. The image analysis system 70 can be located remotely from the vehicle 2.

Some embodiments notify a manager of the vehicle 2 that an item was left behind.

In some embodiments, the maintenance system comprises an image analysis system 70 configured to detect the item left behind by comparing a first baseline image 35 taken by the camera system of the interior of the vehicle 2 to a second image 36 (of the interior) taken by the camera system after the first baseline image 35.

In some embodiments, the maintenance system comprises a communication system 71 having an antenna 19, a transmitter 72, and a receiver 73. The communication system 71 can be configured to send a first wireless communication to a remote computing device 12c associated with a manager of the vehicle 2 in response to the image analysis system 70 detecting the item left behind by the first rider.

As used herein, the “manager” can be a person (other than a rider who is just renting the vehicle 2) or entity who is responsible for the vehicle 2. The manager can be an owner of the vehicle 2. The manager can be a person or entity to whom the owner has entrusted management of the vehicle 2 and/or maintenance of the vehicle 2.

The communication system 71 can be configured to send the first wireless communication to a remote computing device 12 directly (e.g., via radio communications) or indirectly (e.g., via intermediary communication systems 5).

In some embodiments, the first wireless communication is configured to notify the manager that the item was left behind. The communication system 71 can be configured to send a second wireless communication comprising a third image of the item to the remote computing device 12c in response to the image analysis system 70 detecting the item left behind by the first rider.

In some embodiments, the vehicle management system is configured to receive a third wireless communication from the remote computing device in response to the communication system 71 sending the first wireless communication. The third second wireless communication can be configured to instruct the vehicle management system to autonomously drive the vehicle 2 to the first location 8 to remove the item.

In some embodiments, the vehicle management system is configured to determine that the first rider has exited the vehicle 2. The vehicle management system can be configured to cause the camera system to take a first interior image of the interior of the vehicle 2 in response to determining that the first rider has exited the vehicle 2.

In some embodiments, the maintenance system further comprises an image analysis system 70 having at least one processor 77 and a memory 75 comprising program instructions (e.g., code modules configured to be executed by one or more computers) that when executed by the at least one processor are configured to cause the image analysis system 70 to detect the item left behind by analyzing the first interior image taken by the camera system after the first rider has exited the vehicle 2. The first location 8 can be a vehicle cleaning facility. The vehicle management system can be configured to drive the vehicle 2 to the vehicle cleaning facility to remove the item in response to the image analysis system 70 detecting the item.

In some embodiments, the vehicle management system comprises a first mode and a second mode. In the first mode, the vehicle management system can be configured to make the vehicle 2 available to accept a pick-up request of a second rider. In the second mode, the vehicle management system can be configured to make the vehicle 2 unavailable to accept the pick-up request at that time (although the vehicle management system 65 can record the pick-up request such that the vehicle 2 can pick-up the person at a future time, such as after the vehicle 2 has been cleaned). As used herein, “available to accept a pick-up request” means that the vehicle 2 is ready to go pick up the person. As used herein, “unavailable to accept the pick-up request” means that the vehicle 2 is not ready to go pick up the person, but the pick-up can still be scheduled for a future time (e.g., after the vehicle 2 has been cleaned at a cleaning facility).

The vehicle management system can be configured to be in the second mode from a first time at which the image analysis system 70 detects the item left behind. The vehicle management system can be configured to exit the second mode and enter the first mode in response to at least one of the item being removed, receiving an indication that the vehicle 2 has been cleaned, and the vehicle 2 leaving a vehicle cleaning station. In some embodiments, the indication that the vehicle 2 has been cleaned comprises a wireless communication (e.g., from the cleaning facility) that communicates that the vehicle 2 has been cleaned.

In some embodiments, the vehicle management system is configured to determine that the first rider has exited the vehicle 2 in response to (1) receiving a location of a remote computing device 12 associated with the first rider and determining that the location is not inside the vehicle 2, (2) failing to detect a direct wireless communication from the remote computing device 12 to an antenna of the vehicle 2,

(3) determining, by the image analysis system 70, that a second interior image does not show the first rider, and/or (4) determining, by the image analysis system 70, that an infrared image of the interior of the vehicle 2 does not show the first rider.

As used herein, a “direct wireless communication” is a wireless communication that does not use intermediary communication systems 5 for communicative coupling between the remote computing device 12 and an antenna 19 that is mechanically coupled to the vehicle 2. For example, the vehicle 2 can communicate directly with a remote computing device 12 located inside the vehicle 2 via Bluetooth. This Bluetooth communication is one example of a direct wireless communication. Other communication protocols other than Bluetooth can also enable direct wireless communication. Other radio communication systems can enable direct wireless communication.

In some embodiments, the maintenance system comprises at least one processor 77 and a memory 75 comprising program instructions that when executed by the at least one processor cause the maintenance system to (1) compare a first baseline image 35 taken by the camera system of the interior of the vehicle 2 to a second image 36 taken by the camera system after the first baseline image 35 to detect the item left behind by the first rider, and/or (2) drive, by the vehicle management system, the vehicle 2 to the first location 8 to remove the item in response to the detecting the item. The program instructions can comprise code modules configured to be executed by one or more computers located in the vehicle 2 and/or located away from the vehicle 2.

In some embodiments, the first location 8 is a first vehicle cleaning facility. The program instructions can be configured to select the first vehicle cleaning facility based at least in part on determining a distance from the vehicle 2 to the first vehicle cleaning facility and/or based at least in part on determining that the first vehicle cleaning facility is approved by a manager of the vehicle 2.

A manager can receive a list of vehicle cleaning facilities. The list can include prices, services offered, user reviews, and locations. The manager can then select which of the vehicle cleaning facilities she approves. Once approved, the system can select which of the approved facilities to use to clean the vehicle 2 based on many factors including which facility is open, which facility is closest to the current location of the vehicle 2, and which facility will be closest to an anticipated future location of the vehicle 2.

The memory 75 can comprise a list vehicle cleaning facilities that were approved by the manager of the vehicle 2. The program instructions can be configured to choose a cleaning facility that was previously approved by the manager and is located near the current location of the vehicle 2.

In some embodiments, the program instructions are configured to send a first wireless communication to a remote computing device 12 associated with the first rider in response to detecting the item. The first wireless communication can comprise an image of the item. The program instructions can be configured to receive a second wireless communication from the remote computing device 12 in response to sending the first wireless communication. The second wireless communication can comprise an instruction (e.g., from the first rider) to return the item. The program instructions can be configured to drive, by the vehicle management system, the vehicle 2 to the first location 8 in response to the instruction.

One barrier to owners of self-driving vehicles being willing to allow other people to ride in their vehicles (e.g., when the owner is not present) is that owners are concerned

riders will smoke in their vehicles. Smoking can leave a lasting smell that is bothersome to vehicle owners and bothersome to subsequent riders.

When a self-driving vehicle gives rides to riders, there may be times when an owner, manager, or driver is not in the vehicle. As a result, the rider might feel free to smoke in the vehicle. Smoking in the vehicle, however, could substantially damage the value of the vehicle and undermine the experience of future riders. Thus, there is a need for systems and methods are detect smoke inside self-driving vehicles.

Many types of smoke detection systems can be used inside vehicles. Some embodiments use optical smoke detectors, ionization smoke detectors, and camera-based smoke detectors (that use machine vision, image recognition, and/or artificial intelligence to recognize smoke). Smoke detectors can be coupled to a ceiling inside the vehicle (because smoke can float upward) and can be coupled to any location inside the vehicle. In some embodiments, smoke detectors are integrated into a camera system and/or into the dash of the vehicle.

There are many types of optical smoke detectors. In some types, an infrared light beam from a light-emitting diode (“LED”) is projected into a chamber. Holes in an outer covering of the smoke detector can allow smoke to move into the chamber. The chamber can include an electronic light detector (e.g., a photocell) that generates electricity in response to light hitting the electronic light detector. The LED can be oriented in such a way that it is not pointed at the light detector. When smoke enters the chamber, however, the smoke can cause the light beam from the LED to be scattered. Some of the scattered light can hit the light detector. An electronic circuit can monitor the light detector and can determine whether infrared light is hitting the detector. The smoke detector can interpret infrared light hitting the detector as an indication of smoke. The smoke detector can be configured to emit an audio alarm and/or send a wireless communication in response to infrared light hitting the detector.

Some embodiments use photoelectric smoke detectors. Photoelectric smoke detectors can be well suited to detecting certain types of smoke.

Some smoke detection system embodiments comprise ionization smoke detectors. There are many types of ionization smoke detectors. In some embodiments, ionization smoke detectors have a chamber. Holes in an outer housing of the smoke detector can allow smoke to enter the chamber. The chamber can be filled with ions. The ions can come from a chemical element called americium.

Americium can release tiny radioactive particles (called alpha particles), which leak into the detection chamber. As the radioactive particles from the americium enter the chamber, the radioactive particles can collide with air molecules and turn them into positively charged ions and negatively charged electrons. The ions and electrons can move in opposite directions between two electrodes. As long as the ions and electrons are moving, a current flows between the electrodes, which a circuit in the smoke detector can interpret as being an indication that smoke is not present in the vehicle.

If smoke is present, however, smoke particles get into the detector and start to clog up the ionization chamber. The smoke particles attach themselves to the ions and effectively shut off the electric current. The circuit in the detector can detect that change and can interpret the lack of the electrical current as an indication that smoke is present in the vehicle.

When smoke is no longer present in the chamber, the current between the electrodes can resume, which the smoke

detector can determine is an indication of the smoke no longer being present in the vehicle.

Some embodiments have a smoke detection system that uses a camera system to “see” the smoke (and thereby detect the smoke). The camera system can see the smoke by recognizing the distinct shape of smoke moving through the air. For example, a cloud of smoke inside a vehicle has a particular shape that a camera system can recognize as an indication of smoke being present in the vehicle.

The cloud of smoke created by electronic cigarette use has a different appearance (e.g., a different shape, different movement patterns, and different optical properties) than the appearance (e.g., shape, movement patterns, and optical properties) of smoke created by non-electric cigarette smoking. The camera system can thus “see” the difference between a cloud of smoke created by electronic cigarette use and the cloud of smoke created by non-electronic cigarette use.

The maintenance system can include at least one processor and a memory comprising program instructions that when executed by the at least one processor cause the smoke detection system to determine whether the smoke is from electronic cigarette use or is from non-electronic cigarette use by analyzing the appearance (e.g., shape, movement patterns, and optical properties) of the smoke.

In some embodiments, the smoke detection system comprises a camera system and an image analysis system configured to detect the smoke inside the vehicle by comparing a first baseline image taken by the camera system of an interior of the vehicle to a second image taken by the camera system (of the interior of the vehicle) after the first baseline image.

The image analysis system can include at least one processor and a memory comprising program instructions that when executed by the at least one processor cause the image analysis system to compare a first baseline image taken by the camera system of the interior of the vehicle to a second image taken by the camera system after the first baseline image to detect the smoke. The smoke can appear in the second image (e.g., taken by the camera while the rider is smoking) but not appear in the first image (e.g., taken by the camera before the rider started smoking). A visible difference between the two images can be a cloud of smoke.

Many different types of smoke detectors can analyze a size of a particle of the smoke. A small particle of smoke can be indicative of the smoke being from non-electronic cigarette use. A large particle of smoke can be indicative of the smoke being from electronic cigarette use.

As used herein, “smoke” is used broadly to include smoke generated by burning cigarettes and to include aerosol (sometimes called “vapor”) created by electronic cigarette use (sometimes called “vaping”).

As used herein, “cigarettes” are used to burn materials such that the user can inhale the smoke. Cigarettes can burn many substances including, but not limited to tobacco, marijuana, other psychoactive materials, and other materials that people burn to inhale. As used herein, “cigarette” is used broadly and can include a roll of material enclosed in paper and meant to be smoked, but also includes many other smoking devices such as cigars, pipes, bongs, and bubblers.

As used herein, “electronic cigarettes” are used to heat a liquid or other substance to generate an aerosol (which is sometimes called a “vapor”). Some liquids include nicotine, propylene glycol, glycerin, flavorings, and drugs. As used herein, “electronic cigarette” is used broadly and includes all the diverse shapes and types of electronic cigarettes. Some electronic cigarettes include a mouthpiece, a cartridge

(tank), a heating element (atomizer), a microprocessor, and a battery. As used herein, “electronic cigarettes” include vaping devices of all shapes, styles, and sizes and is not limited to vaping devices that have a slim, cylindrical appearance.

Nittan Europe Limited is registered in England and makes a dual optical smoke detector called the EV-DP. Using the scattered light principle inherent in optical detectors, the dual optical smoke detector uses both infrared LEDs and blue LEDs to provide an accurate measurement of particles within the chamber of the smoke detector. By calculating the ratio of these light sources, which operate at different wavelengths, the dual optical smoke detector can determine the particle size and thus distinguish between smoke due to combustion (of cigarettes) and smoke due to aerosol generated by non-combustion products (e.g., vaping devices).

The entire contents of the following patent are incorporated by reference herein: U.S. Pat. No. 6,011,478; issued Jan. 4, 2000; and entitled Smoke Sensor and Monitor control System.

U.S. Pat. No. 6,011,478 describes smoke detection systems that analyze the sizes of particles of smoke. The components described in U.S. Pat. No. 6,011,478 that analyze the sizes of particles of smoke are included in the camera device 10 described herein.

The smoke detection system can also comprise an optical smoke detector (e.g., the EV-DP) configured to analyzing a particle size of the aerosol. The smoke detection system can detect electronic cigarette aerosol by analyzing a particle size of the aerosol and determining that the particle size is indicative of electronic cigarette use (e.g., the particle size is larger than is typical for combustion-generated smoke).

The smoke detection system can determine if the particle size is smaller than a predetermined threshold by directly determining that the particle size is smaller than the threshold. The smoke detection system can also determine if the particle size is smaller than a predetermined threshold by determining that the particle size is larger than the threshold (because by knowing that the particle size is larger than the threshold, the system also effectively knows that the particle size is not smaller than the threshold).

The smoke detection system can determine if the particle size is larger than a predetermined threshold by directly determining that the particle size is larger than the threshold. The smoke detection system can also determine if the particle size is larger than a predetermined threshold by determining that the particle size is smaller than the threshold (because by knowing that the particle size is smaller than the threshold, the system also effectively knows that the particle size is not larger than the threshold).

In some embodiments, rather than use the process of elimination, the smoke detection system actually measures the particles and then determines if the size of each particle is smaller or larger than the threshold. The threshold can be chosen such that being smaller than the threshold is indicative of the particle being cigarette smoke and being larger than the threshold can be indicative of the particle being electronic cigarette aerosol. The maintenance system’s reaction to detecting cigarette smoke can be different (e.g., more extreme) than the maintenance system’s reaction to electronic cigarette aerosol (which is typically less damaging to vehicles).

FIG. 10 illustrates a diagrammatic view of a smoke detection system 74. When the camera device 10 includes at least one smoke detector, the camera device 10 can be a smoke detection system 74. Many types of smoke detectors can be used including ionization smoke detectors 90, optical

smoke detectors 91, camera-based smoke detectors (which can include an image analysis system 70 and cameras 24a, 24b, 24c), and any other type of smoke detector.

The ionization smoke detector 90, the optical smoke detector 91, and the image analysis system 70 can be part of the camera device 10 (e.g., such that they are located inside the device 10). In some embodiments, the ionization smoke detector 90, the optical smoke detector 91, and/or the image analysis system 70 are located outside of the camera device 10, but are still located inside the vehicle 2.

In some embodiments, the image analysis system 70 is located remotely relative to the vehicle 2 such that a camera 24a takes images (which can be videos or still images) of the inside of the vehicle 2 and a communication system 71 sends the images to the image analysis system 70 (which can include a server located far from the vehicle 2). The communication system 71 can send the images to the image analysis system 70 via intermediary communication systems 5. The image analysis system 70 can analyze the images to determine if the images show smoke.

The smoke detection system 74 can be coupled to the vehicle 2 (e.g., to a ceiling of the vehicle 2). The smoke detection system 74 can detect smoke inside the vehicle 2. FIG. 10 illustrates two clouds of smoke 88, 89. A first cloud of smoke 88 includes small particles (which are illustrated as small circles). A second cloud of smoke 89 includes large particles (which are illustrated as large circles). The smoke detection system 74 can analyze the size of the particles in many different ways.

The smoke detection system 74 can use both infrared LEDs and blue LEDs to provide an accurate measurement of particles within the chamber of the smoke detector. By calculating the ratio of these light sources, which operate at different wavelengths, the smoke detection system 74 can determine the particle size and thus distinguish between smoke due to combustion (of cigarettes) and smoke due to aerosol generated by non-combustion products (e.g., vaping devices).

The entire contents of the following patent are incorporated by reference herein: U.S. Pat. No. 6,011,478; issued Jan. 4, 2000; and entitled Smoke Sensor and Monitor Control System. The smoke detection system 74 can use any of the embodiments described in U.S. Pat. No. 6,011,478 to analyze the size of the particles in smoke to determine if the particles are larger or smaller than a predetermined threshold. The threshold can be chosen such that detecting particles larger than the threshold is indicative of the smoke being from non-combustion (e.g., electronic cigarette aerosol) and detecting particles smaller than the threshold is indicative of the smoke being from combustion (e.g., cigarette smoking).

Detecting particles smaller than the threshold (e.g., as indicated by the first cloud of smoke 88) can cause the system to label the event as a combustion (e.g., cigarette smoking) event. The system can send a wireless communication 98 (which may be via intermediary communication systems 5) to a remote computing device 12c of a manager of the vehicle 2. The manager can be an entity responsible for the maintenance of the vehicle 2. The manager can be an owner of the vehicle 2.

FIG. 10 illustrates the remote computing device 12c as a desktop computer, but the remote computing device 12c can be a server, the Cloud, any type of remote computing device described herein or incorporated by reference, or any other suitable computer.

The first wireless communication 98 (which can comprise many wireless communication sessions) can be configured

to enable the remote computing device **12c** to show an image **94** of the rider **1** who was smoking in the vehicle **2**. The image **94** can show the rider **1** in the act of smoking in the vehicle **2** (e.g., to serve as proof that the rider **1** was smoking in the vehicle **2**).

The wireless communication **98** (which can comprise many wireless communication sessions) can comprise data regarding the smoking event. The data can include the name of the rider **1**, an account number of the rider **1**, a ride number, and/or any other data that serves to identify the rider **1**. The wireless communication **98** can also comprise data regarding whether the smoke detected by the smoke detection system **74** was due to non-combustion (e.g., electronic cigarette aerosol) or combustion (e.g., cigarette smoking). The fine due to detecting combustion can be higher than the fine due to non-combustion due to the greater harm caused by combustion smoke (rather than non-combustion smoke) inside the vehicle **2**. The system's reaction to combustion smoke can be more extreme than the system's reaction to non-combustion smoke.

The remote computing device **12c** can be configured to show data **96** regarding the rider **1** and the smoking event of the rider **1**.

Detecting particles larger than the threshold (e.g., as indicated by the second cloud of smoke **89**) can cause the system to label the event as a non-combustion (e.g., vaping) event. The system can send a second wireless communication **99** (which may be via intermediary communication systems **5**) to a remote computing device **12c** of a manager of the vehicle **2**. The remote computing device **12c** shown in the lower right of FIG. **10** illustrates information displayed by the remote computing device **12c** in response to the second wireless communication **99** regarding the non-combustion smoking event.

The second wireless communication **99** (which can comprise many wireless communication sessions) can be configured to enable the remote computing device **12c** to show an image **95** of the rider **1b** who was smoking in the vehicle **2**. The image **95** can show the rider **1b** in the act of smoking in the vehicle **2** (e.g., to serve as proof that the rider **1b** was smoking in the vehicle **2**).

The second wireless communication **99** (which can comprise many wireless communication sessions) can comprise data regarding the smoking event. The data can include the name of the rider **1b**, an account number of the rider **1b**, a ride number, and/or any other data that serves to identify the rider **1b**.

The second wireless communication **99** can also comprise data regarding whether the smoke detected by the smoke detection system **74** was due to non-combustion (e.g., electronic cigarette aerosol) or combustion (e.g., cigarette smoking).

The remote computing device **12c** can be configured to show data **97** regarding the rider **1b** and the smoking event of the rider **1b**.

FIG. **11** illustrates a diagrammatic view of a smoke detection system **74**. FIG. **11** includes a small circle in the ceiling of the vehicle **2**. This small circle illustrates one location (out of many) in which the smoke detection system **74** can be placed inside the vehicle **2**. The smoke detection system **74** can be located inside the cabin of the vehicle **2**.

A remote computing device **12c** of a manager **3** of the vehicle **2** can receive wireless communications from the vehicle **2** (in some cases via intermediary communication system **5**) in response to the vehicle **2** detecting smoke.

The vehicle **2** can include a window **82** motor **81** configured to move a window **82** (of the vehicle **2**) up and down. The motor **81** can be embedded in a door of the vehicle **2**.

The vehicle **2** can include a fan **83** configured to circulate air inside the cabin of the vehicle **2**. In some vehicles **2**, the fan **83** is embedded inside a vent inside the dash.

The vehicle **2** can include a temperature management system **85** having a thermometer, an air conditioner, a heater, and a ventilation system **84**. The temperature management system **85** can be configured to control an ambient temperature inside the cabin of the vehicle **2** by heating or cooling air inside the cabin. In some embodiments, the temperature management system **85** is configured to heat the air inside the cabin to approximately 74 degrees Fahrenheit (e.g., on cold days) and is configured to cool the air inside the cabin to approximately 74 degrees Fahrenheit (e.g., on hot days). In other embodiments, however, the temperature management system **85** is configured to deliberately make the ambient temperature inside the cabin uncomfortably hot or cold in response to the smoke detection system **74** detecting smoke inside the cabin.

On a hot day (with an outside temperature greater than 74 degrees Fahrenheit), the temperature management system **85** can heat the cabin air to a temperature that is greater than 84 degrees Fahrenheit and/or greater than 90 degrees Fahrenheit.

On a cold day (with an outside temperature less than 74 degrees Fahrenheit), the temperature management system **85** can cool the cabin air to a temperature that is less than 64 degrees Fahrenheit, less than 50 degrees Fahrenheit, and/or less than 40 degrees Fahrenheit.

The vehicle **2** can include a speaker **86** configured to emit sounds (e.g., music, audio commands) inside the cabin of the vehicle **2**. In some vehicles **2**, the speaker **86** is embedded inside the dash of the vehicle **2**.

The vehicle **2** can include a rain sensor **87**. The rain sensor **87** can be based on the principle of total internal reflection. An infrared light is beamed at a 45-degree angle into the windshield from the interior of the vehicle **2** (e.g., just behind the windshield of the vehicle **2**). If the windshield glass is wet, less light makes it back to a light sensor than if the windshield glass is dry. Measuring the light that makes it back to the light sensor provides an indication of whether it is raining (because the windshield is wet when it is raining).

The following U.S. patents, the entire contents of which are incorporated herein by reference, describe additional types of rain sensors **87** that can be used with the embodiments described herein: U.S. Pat. Nos. 4,578,995; 4,584,508; 4,987,296; 6,392,218; and 6,341,523. Some embodiments use other types of rain sensors.

Some rain sensor embodiments use a camera (e.g., looking out of a window of the vehicle) to "see" if it is raining outside the vehicle. For example, in 2017 Tesla introduced an update that enabled their cars to utilize onboard cameras to passively detect rain without the use of a dedicated sensor.

Some embodiments comprise a maintenance system configured to be used with a self-driving vehicle **2**. The maintenance system can use a smoke detector to detect smoke inside the vehicle **2** and then can take actions in response to detecting the smoke.

A maintenance system can comprise a smoke detection system **74** configured to detect smoke inside a cabin of the vehicle **2**; a communication system **71** configured to send a first wireless communication to a remote computing device **12c** associated with a manager of the vehicle **2** in response to the smoke detection system **74** detecting the smoke;

and/or a vehicle management system **65** configured to autonomously drive the vehicle **2**.

The vehicle management system **65** can be mechanically coupled to the vehicle **2**. In some embodiments, the vehicle management system **65** is located remotely relative to the vehicle **2**. In some embodiments, a portion of the vehicle management system **65** is mechanically coupled to the vehicle **2** and another portion of the vehicle management system **65** is not mechanically coupled to the vehicle **2** but is be communicatively coupled to the vehicle **2**.

A vehicle management system **65** can be configured to autonomously drive the vehicle **2** even if a rider provides some input such as a destination and even if the rider is told to intervene to drive the vehicle **2** in certain circumstances.

In some embodiments, the smoke detection system **74** comprises a camera system and an image analysis system **70** configured to detect the smoke inside the vehicle **2** by comparing a first baseline image taken by the camera system of an interior of the vehicle **2** to a second image taken by the camera system (of the interior of the vehicle **2**) after the first baseline image.

In some embodiments, a maintenance system comprises a memory **75** having an identification of a first rider of the vehicle **2**. The communication system **71** can comprise an antenna **19**, a transmitter **72**, and/or a receiver **73**. The communication system **71** can be configured to send the identification of the first rider to the remote computing device **12c** of the manager in response to the smoke detection system **74** detecting the smoke inside the vehicle **2**.

Many different types of identifying information can be used as identification of the rider. In some embodiments, the identification is a name of the rider, a picture of the rider, a number or code that represents the rider's account, a credit card number, a social security number, a driver's license number, a number or code that represents the ride that the rider took, and/or any information configured to help identify the rider.

In some embodiments, a maintenance system comprises a camera system coupled to an interior of the vehicle **2**. The camera system can be configured to take a picture of a first rider smoking. The communication system **71** can be configured to send the picture of the first rider smoking to the remote computing device **12c**.

In some embodiments, the camera system comprises a first camera directed towards a first row of the vehicle **2**. The first camera can be configured to take the picture in response to the smoke detection system **74** detecting the smoke inside the vehicle **2**.

In some embodiments, the smoke detection system **74** comprises an ionization smoke detector **90** configured to detect cigarette smoking. The smoke detection system **74** can also comprise an optical smoke detector **90** configured to detect electronic cigarette aerosol by analyzing a particle size of the aerosol and determining that the particle size is indicative of electronic cigarette use.

As used herein, smoke can include aerosol generated by "vaping" and also smoke generated by burning cigarettes.

Electronic cigarettes can include all types of devices used to heat a liquid to generate an aerosol, commonly called a "vapor," that the user inhales.

Cigarettes can be used to burn many psychoactive materials including tobacco and marijuana.

In some embodiments, the smoke detection system **74** comprises at least one optical smoke detector **90** configured to analyze a particle size of the smoke. The communication system **71** is configured to send the first wireless communication identifying the smoke as an aerosol in response to

the smoke detection system **74** determining that the particle size is greater than a predetermined threshold. The communication system **71** can be configured to send the first wireless communication identifying the smoke as cigarette smoking in response to the smoke detection system **74** determining that the particle size is less than the predetermined threshold.

The first wireless communication can comprise multiple wireless communications and is not limited to a single communication instance. The first wireless communication can comprise many wireless communication sessions.

In some embodiments, a camera system is coupled to an interior of the vehicle **2**. The camera system can be configured to take a picture of a first rider smoking. The communication system **71** can be configured to send the picture of the first rider smoking to the remote computing device **12c**. The first wireless communication **98** can be configured to enable the remote computing device **12c** to display the picture of the first rider smoking and to display an indication **96** of whether the smoke is due to the aerosol or the cigarette smoking.

The vehicle management system **65** can automatically take many actions in response to the smoke detector detecting smoke.

In some embodiments, the vehicle management system **65** comprises a motor **81** configured to roll down a window **82** of the vehicle **2**. The vehicle management system **65** can be configured to use the motor **81** to automatically roll down the window **82** in response to the smoke detection system **74** detecting the smoke inside the vehicle **2**.

In some embodiments, the vehicle management system **65** comprises a ventilation system **84** having a fan **83** to push air in the cabin. The fan **83** can be located inside the dash of the vehicle **2** such that the fan **83** pushes air in the cabin by pushing air through a vent and into the cabin. The vehicle management system **65** can be configured to automatically increase a rate at which the ventilation system **84** pushes outside air into the cabin of the vehicle **2** in response to the smoke detection system **74** detecting the smoke inside the vehicle **2**. In several embodiments, the rate is increased by increasing a rotational speed of the fan **83**.

In some embodiments, the vehicle management system **65** comprises a ventilation system **84**, and the vehicle management system **65** is configured to use the ventilation system **84** to automatically inject outside air into the cabin of the vehicle **2** in response to the smoke detection system **74** detecting the smoke inside the vehicle **2**.

In some embodiments, the vehicle management system **65** comprises a temperature management system **85** having a thermometer and having at least one of an air conditioner, a heater, and a ventilation system **84** having a fan **83** to circulate air in the cabin. The fan **83** can be located inside a vent inside the dash of the vehicle **2** such that the fan **83** is configured to circulate air in the cabin by pushing air out from a vent. The vehicle management system **65** can be configured to at least one of increase and decrease an ambient temperature inside the cabin by at least ten degrees Fahrenheit in response to the smoke detection system **74** detecting the smoke inside the vehicle **2** to decrease a comfort level of a first rider.

In some embodiments, the vehicle management system **65** is configured to decrease an ambient temperature inside the cabin by at least ten degrees Fahrenheit and/or by at least twenty degrees Fahrenheit in response to the smoke detection system **74** detecting the smoke inside the vehicle **2** to decrease a comfort level of a first rider. The vehicle management system **65** can be configured to increase an ambient

temperature inside the cabin by at least ten degrees Fahrenheit and/or by at least twenty degrees Fahrenheit in response to the smoke detection system 74 detecting the smoke inside the vehicle 2 to decrease a comfort level of a first rider.

In some embodiments, the vehicle management system 65 is configured to determine a local speed limit and is configured to automatically reduce a speed of the vehicle 2 below the local speed limit in response to the smoke detection system 74 detecting the smoke inside the vehicle 2.

In some embodiments, the vehicle management system 65 determines the local speed limit by receiving the local speed limit from a remote system (e.g., via a wireless communication to the vehicle management system 65).

In some embodiments, the vehicle management system 65 comprises data regarding speed limits of each area (e.g., street section) of a map. The vehicle management system 65 can determine the local speed limit by determining a location of the vehicle 2 and then using that location to determine which speed limit applies to the area of the location.

Some embodiments include reducing the speed so much that the vehicle 2 stops (e.g., such that the vehicle 2 is parked). The vehicle management system 65 can be configured to determine a suitable parking location in response to the smoke detection system 74 detecting the smoke inside the vehicle 2, and the vehicle management system 65 can be configured to park the vehicle 2 in the parking location in response to the smoke detection system 74 detecting the smoke inside the vehicle 2.

In some embodiments, the vehicle management system 65 comprises a speaker 86. The speaker 86 can be configured to emit audio commands instructing a first rider of the vehicle 2 to cease smoking in order to cause the vehicle management system 65 to increase the speed and/or start moving again after being stopped in a parking location. The audio commands can be words such as, "John, the car has stopped because it has detected that you are smoking. The car will not start moving again until you stop smoking. You have been fined \$50 and will be fined an even larger amount if you do not stop smoking within 60 seconds."

Getting the rider to stop smoking right away is advantageous because additional time smoking will result in additional damage to the vehicle 2. A vehicle 2 that has been smoked in for 10 seconds typically will not smell as bad as a vehicle 2 that has been smoked in for 10 minutes.

Some embodiments comprise a first financial penalty for smoking and additional financial penalties for continuing to smoke inside the vehicle. The vehicle 2 can be configured to provide a ride to a first rider. The vehicle management system 65 can be configured to fine an account 81 of the first rider a first amount in response to the smoke detection system detecting the smoke inside the vehicle 2. The vehicle management system 65 can be configured to notify the first rider that the account 81 will be fined a second amount if the smoke detection system detects the smoke at a later time during the ride. The vehicle management system 65 can be configured to fine the account 81 the second amount in response to the smoke detection system detecting the smoke at the later time during the ride. The second amount can be greater than the first amount. The second amount can be at least forty percent greater than the first amount such that the large second amount is a strong deterrent to the rider deciding to continue smoking in the vehicle 2.

In some embodiments, the vehicle 2 is configured to drive a first rider to a destination selected by the first rider. The vehicle management system 65 can be configured to cease

driving towards the destination in response to the smoke detection system 74 detecting the smoke inside the vehicle 2. The vehicle 2 can pull over to the side of the road. The vehicle 2 can determine a suitable parking location and then can cease driving towards the destination by going to the parking location. The vehicle 2 can cease driving towards the destination by driving away from the destination. The vehicle management system 65 can be configured to continue driving towards the destination once the smoke detection system 74 no longer detects the smoke inside the vehicle 2.

In some embodiments, the vehicle management system 65 is configured to fine an account 81 of a first rider of the vehicle 2 in response to the smoke detection system 74 detecting the smoke inside the vehicle 2. The smoke detection system 74 can be configured to analyze a particle size of the smoke to determine if the particle size is larger than a predetermined threshold. The vehicle management system 65 can be configured to fine the account 81 a first amount if the particle size is larger than the predetermined threshold. The vehicle management system 65 can be configured to fine the account 81 a second amount if the particle size is smaller than the predetermined threshold. The second amount can be larger than the first amount and/or at least 20 percent larger than the first amount.

In some embodiments, the vehicle management system 65 comprises a lighting system 100 having at least one light coupled to an interior of the vehicle 2. The lighting system 100 can be configured to illuminate at least one of a seat of the vehicle 2 and a majority of the cabin. The vehicle management system 65 can be configured to use the lighting system 100 to illuminate at least one of the seat and the majority of the cabin in response to the smoke detection system 74 detecting the smoke inside the vehicle 2.

The light can be a spotlight to illuminate a seat in which the rider that is smoking is sitting. The light can be an LED. The light can be multiple LEDs.

In some embodiments, the vehicle management system 65 comprises a speaker 86. The speaker 86 can be configured to emit audio commands instructing a first rider of the vehicle 2 to cease smoking. The vehicle management system 65 can be configured to cease illuminating the majority of the cabin and/or cease illuminating the seat in response to the smoke detection system 74 no longer detecting the smoke inside the vehicle 2.

The vehicle management system 65 can cause the vehicle 2 to go to a service area 8 to clean the vehicle 2. Cleaning the vehicle 2 can help remove the smoke smell.

In some embodiments, the vehicle management system 65 is configured to receive a first location of a service area 8 configured to clean the vehicle 2. The vehicle management system 65 can be configured to drive the vehicle 2 to the service area 8 in response to the smoke detection system 74 detecting the smoke inside the vehicle 2.

In some embodiments, the smoke detection system 74 is configured to detect the smoke emitted by a first rider while the vehicle 2 is driving to a drop off location of the first rider. The vehicle management system 65 can comprise a first mode and a second mode. In the first mode, the vehicle management system 65 is configured to make the vehicle 2 available to accept a pick-up request of a second rider. In the second mode, the vehicle management system 65 is configured to make the vehicle 2 unavailable to accept the pick-up request. The vehicle management system 65 can be configured to enter the second mode in response to the smoke detection system 74 detecting the smoke inside the vehicle 2. The vehicle management system 65 can be configured to

exit the second mode and enter the first mode in response to at least one of receiving an indication that the vehicle 2 has been cleaned and the vehicle 2 leaving a vehicle cleaning station.

In some embodiments, the vehicle management system 65 comprises a ventilation system 84 having a fan 83 to push air in the cabin. The fan 83 can be embedded in a vent channel of the dash or can be located in any other suitable location. The smoke detection system 74 can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system 65 can be configured to automatically increase a rate at which the ventilation system 84 pushes outside air into the cabin in response to the smoke detection system 74 detecting the smoke inside the vehicle 2. The vehicle management system 65 can be configured to drive the vehicle 2 to a service area 8 configured to clean the vehicle 2 in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system 65 comprises a motor 81 configured to roll down a window 82 of the vehicle 2. The smoke detection system 74 is configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system 65 can be configured to use the motor 81 to automatically roll down the window 82 in response to the smoke detection system 74 detecting the smoke inside the vehicle 2. The vehicle management system 65 can be configured to drive the vehicle 2 to a service area 8 configured to clean the vehicle 2 in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system 65 comprises at least one of a motor 81 configured to roll down a window 82 of the vehicle 2 and a ventilation system 84 having a fan 83 to push air in the cabin. The smoke detection system 74 can be configured to detect the smoke emitted by a first rider while the vehicle 2 is driving to a drop off location of the first rider. The smoke detection system 74 can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold.

In some embodiments, in response to the smoke detection system 74 detecting the smoke inside the vehicle 2, the vehicle management system 65 is configured to at least one of use the motor 81 to automatically roll down the window 82 and increase a rate at which the ventilation system 84 pushes the air into the cabin.

In some embodiments, in response to determining that the particle size is larger than the predetermined threshold and after at least one of rolling down the window 82 and increasing the rate, the vehicle management system 65 is configured to make the vehicle 2 available to pick up a second rider.

In some embodiments, in response to determining that the particle size is smaller than the predetermined threshold, the vehicle management system 65 is configured to make the vehicle 2 unavailable to pick up the second rider until after the vehicle management system 65 has driven the vehicle 2 to a service area 8 configured to clean the vehicle 2.

In some embodiments, the vehicle management system 65 comprises a motor 81 configured to roll down a window 82 of the vehicle 2 and a rain sensor 87 configured to detect an indication of rain on the vehicle 2. The smoke detection system 74 can be configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold. The vehicle management system

65 can be configured to use the motor 81 to automatically roll down the window 82 in response to the smoke detection system 74 detecting the smoke inside the vehicle 2 and/or in response to the rain sensor 87 not detecting the indication of the rain. The vehicle management system 65 can be configured to drive the vehicle 2 to a service area 8 configured to clean the vehicle 2 in response to determining that the particle size is smaller than the predetermined threshold.

In some embodiments, the vehicle management system 65 comprises a motor 81 configured to roll down a window 82 of the vehicle 2 and a rain sensor 87 configured to detect an indication of rain on the vehicle 2. The vehicle management system 65 can be configured to use the motor 81 to automatically roll down the window 82 in response to the smoke detection system 74 detecting the smoke inside the vehicle 2 and in response to the rain sensor 87 not detecting the indication of the rain.

Interpretation

To reduce unnecessary redundancy, not every element or feature is described in the context of every embodiment, but all elements and features described in the context of any embodiment herein and/or incorporated by reference can be combined with any elements and/or features described in the context of any other embodiments.

The self-driving vehicle 2 can be any suitable vehicle. For example, the self-driving vehicle 2 can be a Tesla Model S made by Tesla, Inc. The Tesla Model S can include the Enhanced Autopilot package and the Full Self-Driving Capability package. The Full Self-Driving Capability package includes eight active cameras to enable full self-driving in almost all circumstances.

The self-driving vehicle 2 can also be a Waymo car. Waymo was formerly the Google self-driving car project. Waymo, which is owned by Alphabet Inc., has logged thousands of self-driving miles over many years. Waymo vehicles have sensors and software that are designed to detect pedestrians, cyclists, vehicles, roadwork and more from a distance of up to two football fields away in all directions. Waymo has stated that its software leverages over four million miles of real world driving data. In some embodiments, self-driving vehicles sometimes drive themselves, sometimes are driven remotely by a computing system, and sometimes are driven manually by a human turning a steering wheel, operating pedals, and performing other driver functions. In several embodiments, a self-driving vehicle drives without a human inside the vehicle to pick up the human and then lets the human drive the vehicle. Although in some cases, the human may choose not to drive the vehicle and instead may allow the vehicle to drive (e.g., steer and control speed) itself (e.g., in response to a destination requested by the human).

The remote computing device 12 can be a smartphone, a tablet computer, a laptop computer, a desktop computer, a server, augmented reality glasses, an implanted computer, and/or any type of computer. A rider can bring her remote computing device 12 into the self-driving vehicle 2 and then can leave the self-driving vehicle 2 with her remote computing device 12. In some embodiments, the rider requests a ride at her home with a remote computing device 12, but then leaves the remote computing device 12 at home when she goes to get a ride from the vehicle 2.

In some embodiments, the remote computing device 12 is an iPhone made by Apple Inc. or an Android phone based on software made by Alphabet Inc. The remote computing device 12 can comprise a speaker configured to emit sounds, a microphone configured to record sounds, and a display screen configured to display images. The remote computing

device 12 can comprise a battery configured to provide electrical power to operate the remote computing device 12.

In some embodiments, portions of the vehicle management system 65 can be physically coupled to the self-driving vehicle 2 while other portions of the vehicle management system 65 are not physically coupled to the vehicle 2 and are located remotely relative to the vehicle 2.

In some embodiments, at least a portion of the vehicle management system 65 is located in the vehicle 2. In several embodiments, at least a portion of the vehicle management system 65 is located remotely relative to the vehicle 2. The vehicle management system 65 can comprise many servers, computers, and vehicles. The vehicle management system 65 can comprise cloud computing and cloud storage.

In several embodiments, the entire vehicle management system 65 is located in the self-driving vehicle 2. The vehicle 2 can comprise the vehicle management system 65. In some embodiments, a first portion of the vehicle management system 65 is physically coupled to the vehicle 2, and a second portion of the vehicle management system 65 is not physically coupled to the vehicle 2. The second portion can be located remotely relative to the vehicle 2. In several embodiments, the entire vehicle management system 65 is located remotely relative to the vehicle 2.

The phrase “communicatively coupling” can include any type of direct and/or indirect coupling between the self-driving vehicle 2, remote computing device 12, and vehicle management system 65. For example, the remote computing device 12 can be communicatively coupled to the vehicle management system 65 via servers, the Cloud, the Internet, satellites, Wi-Fi networks, cellular networks, and any other suitable communication means.

Some of the devices, systems, embodiments, and processes use computers. Each of the routines, processes, methods, and algorithms described in the preceding sections may be embodied in, and fully or partially automated by, code modules executed by one or more computers, computer processors, or machines configured to execute computer instructions. The code modules may be stored on any type of non-transitory computer-readable storage medium or tangible computer storage device, such as hard drives, solid state memory, flash memory, optical disc, and/or the like. The processes and algorithms may be implemented partially or wholly in application-specific circuitry. The results of the disclosed processes and process steps may be stored, persistently or otherwise, in any type of non-transitory computer storage such as, e.g., volatile or non-volatile storage.

The term “app”, as used in this disclosure, refers to both native apps and mobile cloud apps (and Web apps). Native apps are installed directly on remote computing devices, whereby developers create separate app versions for each type of remote computing device (e.g., iPhone devices and Android devices). Native apps may be stored on the remote computing device out of the box, or the native apps can be downloaded from a public or private app store and installed on the remote computing device. Self-driving vehicle data associated with native apps can be stored on the remote computing device and/or can be stored remotely and accessed by the native app. Internet connectivity may be used by some instances of apps. Other instances of apps may not use Internet connectivity. In some embodiments, apps can function without Internet connectivity.

Mobile cloud apps are very similar to Web-based apps. The main similarity is that both mobile cloud apps and Web apps run on servers external to the remote computing device and may require the use of a browser on the remote computing device to display and then use the app user

interface (UI). Mobile cloud apps can be native apps rebuilt to run in the mobile cloud; custom apps developed for mobile devices; or third-party apps downloaded to the cloud from external sources. Some organizations offer both a native and mobile cloud versions of their applications. In short, the term “app” refers to both native apps and mobile cloud apps.

None of the steps described herein is essential or indispensable. Any of the steps can be adjusted or modified. Other or additional steps can be used. Any portion of any of the steps, processes, structures, and/or devices disclosed or illustrated in one embodiment, flowchart, or example in this specification can be combined or used with or instead of any other portion of any of the steps, processes, structures, and/or devices disclosed or illustrated in a different embodiment, flowchart, or example. The embodiments and examples provided herein are not intended to be discrete and separate from each other.

The section headings and subheadings provided herein are nonlimiting. The section headings and subheadings do not represent or limit the full scope of the embodiments described in the sections to which the headings and subheadings pertain. For example, a section titled “Topic 1” may include embodiments that do not pertain to Topic 1 and embodiments described in other sections may apply to and be combined with embodiments described within the “Topic 1” section.

Some of the devices, systems, embodiments, and processes use computers. Each of the routines, processes, methods, and algorithms described in the preceding sections may be embodied in, and fully or partially automated by, code modules executed by one or more computers, computer processors, or machines configured to execute computer instructions. The code modules may be stored on any type of non-transitory computer-readable storage medium or tangible computer storage device, such as hard drives, solid state memory, flash memory, optical disc, and/or the like. The processes and algorithms may be implemented partially or wholly in application-specific circuitry. The results of the disclosed processes and process steps may be stored, persistently or otherwise, in any type of non-transitory computer storage such as, e.g., volatile or non-volatile storage.

The various features and processes described above may be used independently of one another, or may be combined in various ways. All possible combinations and subcombinations are intended to fall within the scope of this disclosure. In addition, certain method, event, state, or process blocks may be omitted in some implementations. The methods, steps, and processes described herein are also not limited to any particular sequence, and the blocks, steps, or states relating thereto can be performed in other sequences that are appropriate. For example, described tasks or events may be performed in an order other than the order specifically disclosed. Multiple steps may be combined in a single block or state. The example tasks or events may be performed in serial, in parallel, or in some other manner. Tasks or events may be added to or removed from the disclosed example embodiments. The example systems and components described herein may be configured differently than described. For example, elements may be added to, removed from, or rearranged compared to the disclosed example embodiments.

Conditional language used herein, such as, among others, “can,” “could,” “might,” “may,” “e.g.,” and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do

not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment. The terms “comprising,” “including,” “having,” and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations and so forth. Also, the term “or” is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term “or” means one, some, or all of the elements in the list. Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present.

The term “and/or” means that “and” applies to some embodiments and “or” applies to some embodiments. Thus, A, B, and/or C can be replaced with A, B, and C written in one sentence and A, B, or C written in another sentence. A, B, and/or C means that some embodiments can include A and B, some embodiments can include A and C, some embodiments can include B and C, some embodiments can only include A, some embodiments can include only B, some embodiments can include only C, and some embodiments can include A, B, and C. The term “and/or” is used to avoid unnecessary redundancy.

While certain example embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions disclosed herein. Thus, nothing in the foregoing description is intended to imply that any particular feature, characteristic, step, module, or block is necessary or indispensable. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions, and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions disclosed herein.

The following is claimed:

1. A maintenance system configured to be used with a self-driving vehicle, the maintenance system comprising:
 - a smoke detection system configured to detect smoke inside a cabin of the vehicle;
 - a communication system configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the smoke detection system detecting the smoke;
 - a vehicle management system configured to autonomously drive the vehicle; and
 - a memory having an identification of a first rider of the vehicle, wherein the communication system is configured to send the identification of the first rider to the remote computing device of the manager in response to the smoke detection system detecting the smoke inside the vehicle.
2. The maintenance system of claim 1, wherein the smoke detection system comprises a camera system and an image analysis system configured to detect the smoke inside the vehicle by comparing a first baseline image taken by the

camera system of an interior of the vehicle to a second image taken by the camera system after the first baseline image.

3. The maintenance system of claim 1, wherein the smoke detection system comprises an ionization smoke detector configured to detect cigarette smoking and comprises an optical smoke detector configured to detect electronic cigarette aerosol by analyzing a particle size of the aerosol and determining that the particle size is indicative of electronic cigarette use.

4. The maintenance system of claim 1, wherein the smoke detection system comprises at least one optical smoke detector configured to analyze a particle size of the smoke, wherein the communication system is configured to send the first wireless communication identifying the smoke as an aerosol in response to the smoke detection system determining that the particle size is greater than a predetermined threshold, and the communication system is configured to send the first wireless communication identifying the smoke as cigarette smoking in response to the smoke detection system determining that the particle size is less than the predetermined threshold.

5. The maintenance system of claim 1, wherein the first wireless communication is configured to enable the remote computing device to display an indication of whether the smoke is due to aerosol or cigarette smoking.

6. The maintenance system of claim 1, wherein the vehicle management system comprises a motor configured to roll down a window of the vehicle, and the vehicle management system is configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle.

7. The maintenance system of claim 1, wherein the vehicle management system comprises a ventilation system having a fan to push air into the cabin, and the vehicle management system is configured to automatically increase a rate at which the ventilation system pushes the air into the cabin of the vehicle in response to the smoke detection system detecting the smoke inside the vehicle.

8. The maintenance system of claim 1, wherein the vehicle management system comprises a temperature management system having a thermometer and having at least one of an air conditioner, a heater, and a ventilation system having a fan to circulate air in the cabin, and the vehicle management system is configured to at least one of increase and decrease an ambient temperature inside the cabin by at least ten degrees Fahrenheit in response to the smoke detection system detecting the smoke inside the vehicle to decrease a comfort level of the first rider.

9. The maintenance system of claim 1, wherein the vehicle management system is configured to determine a local speed limit and is configured to automatically reduce a speed of the vehicle below the local speed limit in response to the smoke detection system detecting the smoke inside the vehicle.

10. The maintenance system of claim 1, wherein the vehicle management system comprises a first mode and a second mode, wherein in the first mode the vehicle management system is configured to make the vehicle available to accept a pick-up request of a second rider, and in the second mode the vehicle management system is configured to make the vehicle unavailable to accept the pick-up request, and the vehicle management system is configured to enter the second mode in response to the smoke detection system detecting the smoke inside the vehicle.

11. The maintenance system of claim 1, wherein the smoke detection system is configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold, and

the vehicle management system is configured to drive the vehicle to a service area configured to clean the vehicle in response to determining that the particle size is smaller than the predetermined threshold.

12. The maintenance system of claim 1, wherein the smoke detection system is configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold, and

in response to determining that the particle size is smaller than the predetermined threshold, the vehicle management system is configured to make the vehicle unavailable to pick up a second rider.

13. The maintenance system of claim 1, wherein the vehicle management system comprises a motor configured to roll down a window of the vehicle and a rain sensor configured to detect an indication of rain on the vehicle, and the vehicle management system is configured to use the motor to automatically roll down the window in response to the smoke detection system detecting the smoke inside the vehicle and in response to the rain sensor not detecting the indication of the rain.

14. The maintenance system of claim 1, wherein the identification comprises a picture of the first rider.

15. The maintenance system of claim 1, wherein the vehicle management system is configured to automatically reduce a speed of the vehicle in response to the smoke detection system detecting the smoke inside the vehicle.

16. The maintenance system of claim 1, wherein the vehicle management system is configured to make the vehicle unavailable to pick up a second rider in response to the smoke detection system detecting the smoke.

17. A maintenance system configured to be used with a self-driving vehicle, the maintenance system comprising:

a smoke detection system configured to detect smoke inside a cabin of the vehicle;

a communication system configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the smoke detection system detecting the smoke;

a vehicle management system configured to autonomously drive the vehicle; and

a camera system coupled to an interior of the vehicle, wherein the camera system is configured to take a picture of a first rider smoking, and the communication system is configured to send the picture of the first rider smoking to the remote computing device.

18. The maintenance system of claim 17, wherein the camera system comprises a first camera, and the first camera is configured to take the picture in response to the smoke detection system detecting the smoke inside the vehicle.

19. The maintenance system of claim 17, wherein the vehicle is configured to drive the first rider to a destination selected by the first rider, and the vehicle management system is configured to cease driving toward the destination in response to the smoke detection system detecting the smoke inside the vehicle.

20. The maintenance system of claim 17, wherein the vehicle management system comprises a lighting system having at least one light coupled to the interior of the vehicle, the lighting system is configured to illuminate at least one of a seat of the vehicle and a majority of the cabin, and the vehicle management system is configured to use the

lighting system to illuminate at least one of the seat and the majority of the cabin in response to the smoke detection system detecting the smoke inside the vehicle.

21. The maintenance system of claim 17, wherein the vehicle management system is configured to make the vehicle unavailable to pick up a second rider in response to the smoke detection system detecting the smoke.

22. The maintenance system of claim 17, wherein the smoke detection system comprises the camera system and an image analysis system configured to detect the smoke inside the vehicle by comparing a first baseline image taken by the camera system of the interior of the vehicle to a second image taken by the camera system after the first baseline image.

23. A maintenance system configured to be used with a self-driving vehicle, the maintenance system comprising:

a smoke detection system configured to detect smoke inside a cabin of the vehicle;

a communication system configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the smoke detection system detecting the smoke; and

a vehicle management system configured to autonomously drive the vehicle, wherein the maintenance system is configured to fine an account of a first rider of the vehicle in response to the smoke detection system detecting the smoke inside the vehicle.

24. The maintenance system of claim 23, wherein the smoke detection system is configured to analyze a particle size of the smoke to determine if the particle size is larger than a predetermined threshold, the maintenance system is configured to fine the account a first amount if the particle size is larger than the predetermined threshold, the maintenance system is configured to fine the account a second amount if the particle size is smaller than the predetermined threshold, and the second amount is at least 20 percent larger than the first amount.

25. The maintenance system of claim 23, wherein the vehicle is configured to provide a ride to the first rider, the maintenance system is configured to fine the account of the first rider a first amount in response to the smoke detection system detecting the smoke inside the vehicle, the maintenance system is configured to notify the first rider that the account will be fined a second amount if the smoke detection system detects the smoke at a later time during the ride, and the maintenance system is configured to fine the account the second amount in response to the smoke detection system detecting the smoke at the later time during the ride.

26. The maintenance system of claim 23, wherein the first wireless communication is configured to enable the remote computing device to display an indication of whether the smoke is due to aerosol or cigarette smoking.

27. A maintenance system configured to be used with a self-driving vehicle, the maintenance system comprising:

a smoke detection system configured to detect smoke inside a cabin of the vehicle;

a communication system configured to send a first wireless communication to a remote computing device associated with a manager of the vehicle in response to the smoke detection system detecting the smoke; and

a vehicle management system configured to autonomously drive the vehicle, wherein the vehicle management system is configured to receive a first location of a service area configured to clean the vehicle, and the vehicle management system is configured to drive the

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vehicle to the service area in response to the smoke detection system detecting the smoke inside the vehicle.

28. The maintenance system of claim 27, wherein the first wireless communication is configured to enable the remote computing device to display an indication of whether the smoke is due to aerosol or cigarette smoking.

29. The maintenance system of claim 27, wherein the smoke detection system is configured to detect the smoke emitted by the first rider while the vehicle is driving to a drop-off location of the first rider,

the maintenance system comprises a first mode and a second mode, wherein in the first mode the maintenance system is configured to make the vehicle available to accept a pick-up request of a second rider, and in the second mode the maintenance system is configured to make the vehicle unavailable to accept the pick-up request,

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the maintenance system is configured to enter the second mode in response to the smoke detection system detecting the smoke inside the vehicle, and

the maintenance system is configured to exit the second mode and enter the first mode in response to at least one of receiving an indication that the vehicle has been cleaned and the vehicle leaving the service area.

30. The maintenance system of claim 27, wherein the smoke detection system is configured to analyze a particle size of the smoke to determine if the particle size is smaller than a predetermined threshold, and

the vehicle management system is configured to drive the vehicle to the service area in response to the smoke detection system detecting the smoke inside the vehicle and determining that the particle size is smaller than the predetermined threshold.

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